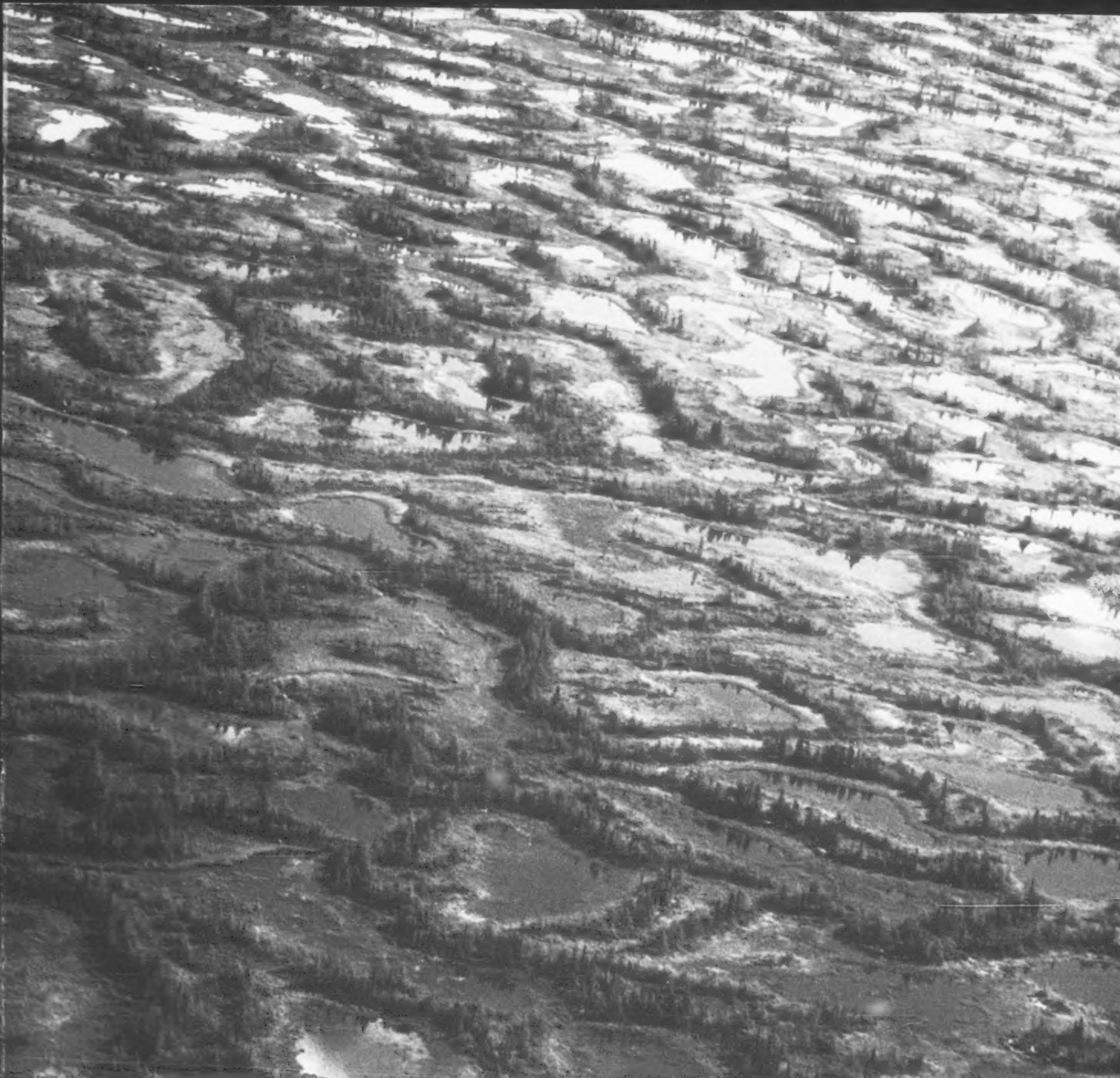
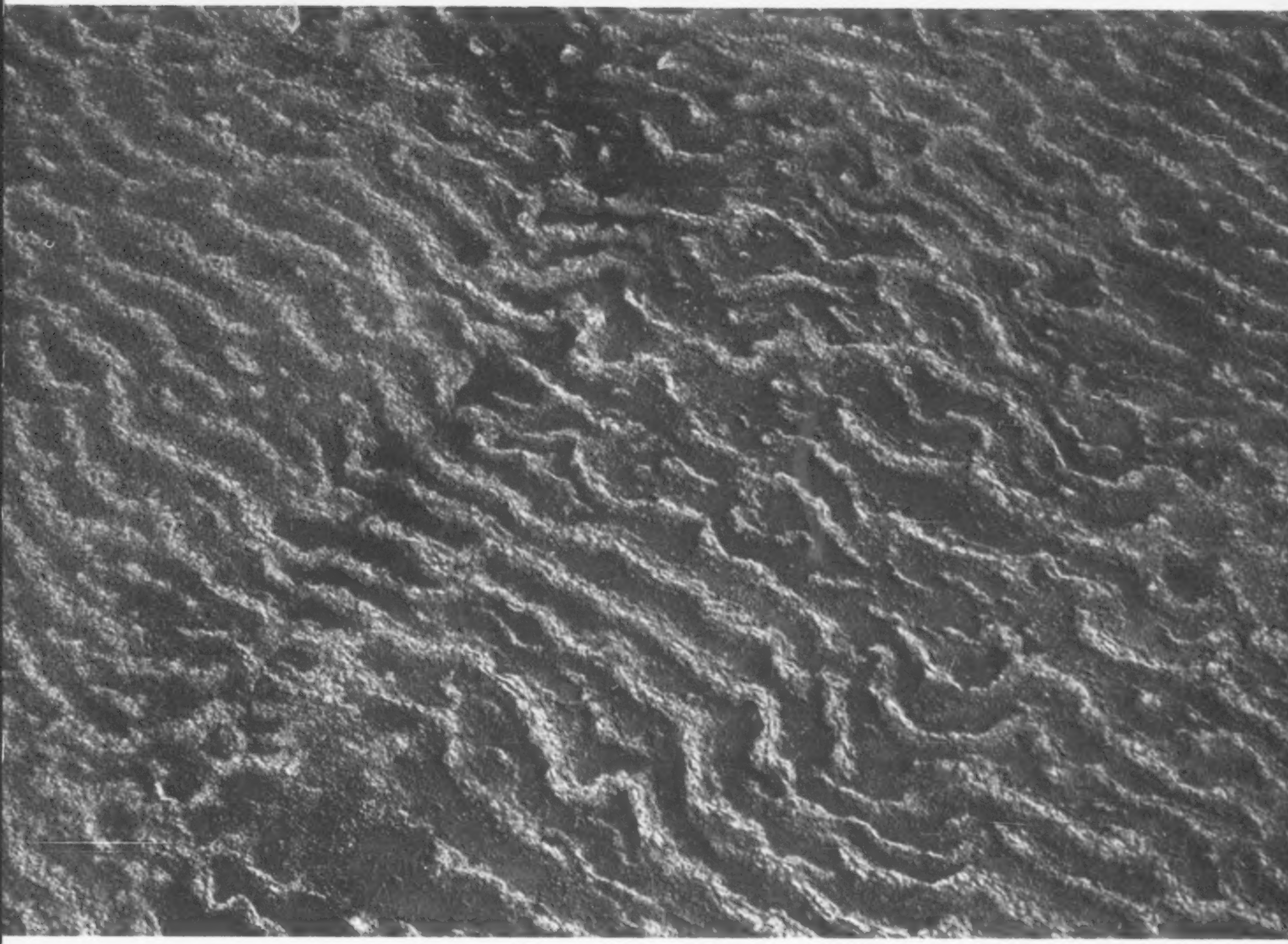


WETLANDS OF THE HUDSON BAY LOWLAND

JOHN L. RILEY



WETLANDS OF THE HUDSON BAY LOWLAND

AN ONTARIO OVERVIEW

John L. Riley

Nature Conservancy Canada

Ontario

A partnership project of the Nature Conservancy of Canada and the Ontario Ministry of Natural Resources

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The Nature Conservancy of Canada is a non-profit, non-advocacy organization committed to land conservation and the preservation of Canada's biodiversity, based on best available science and in partnership with many organizations and agencies. Since 1962, NCC and its partners and supporters have protected more than 800,000 hectares (2 million acres) across Canada.

Under Ontario's **Far North Land Use Planning Initiative**, First Nation communities are leading the development of community-based land use plans and working jointly with the Ontario Ministry of Natural Resources (MNR). Land use planning will enable First Nations in the Far North, along with Ontario, to dedicate areas for protection and to identify areas suitable for sustainable economic development opportunities. To support this planning initiative, the MNR's Far North Branch is working with partners to determine information needs, establish priorities, and support scientific inventory and mapping of the region's biodiversity and natural resources. The Far North Natural Heritage Project, led by the MNR's Parks and Protected Areas Policy Section, is part of these ongoing efforts. The report "Wetlands of the Hudson Bay Lowland: An Ontario Overview" contributes to our knowledge of Ontario's Far North, and is one product of a creative partnership between Parks and Protected Areas Policy Section and the Nature Conservancy of Canada.

DESIGN AND LAYOUT: Judie Shore

FRONT COVER. Hudson Bay Lowland, 27km from Hudson Bay, 1km west of Winisk River.

BACK COVER. Wetland 33km west of North Point, James Bay; net fen of open pools terraced with treed and open shrub fen ribs.

TITLE PAGE. Open ribbed fen, southwest James Bay interior.

BELOW. Southern interior bog and fen plateau on higher ground between Albany and Moose basins in Kinoje Lake area.

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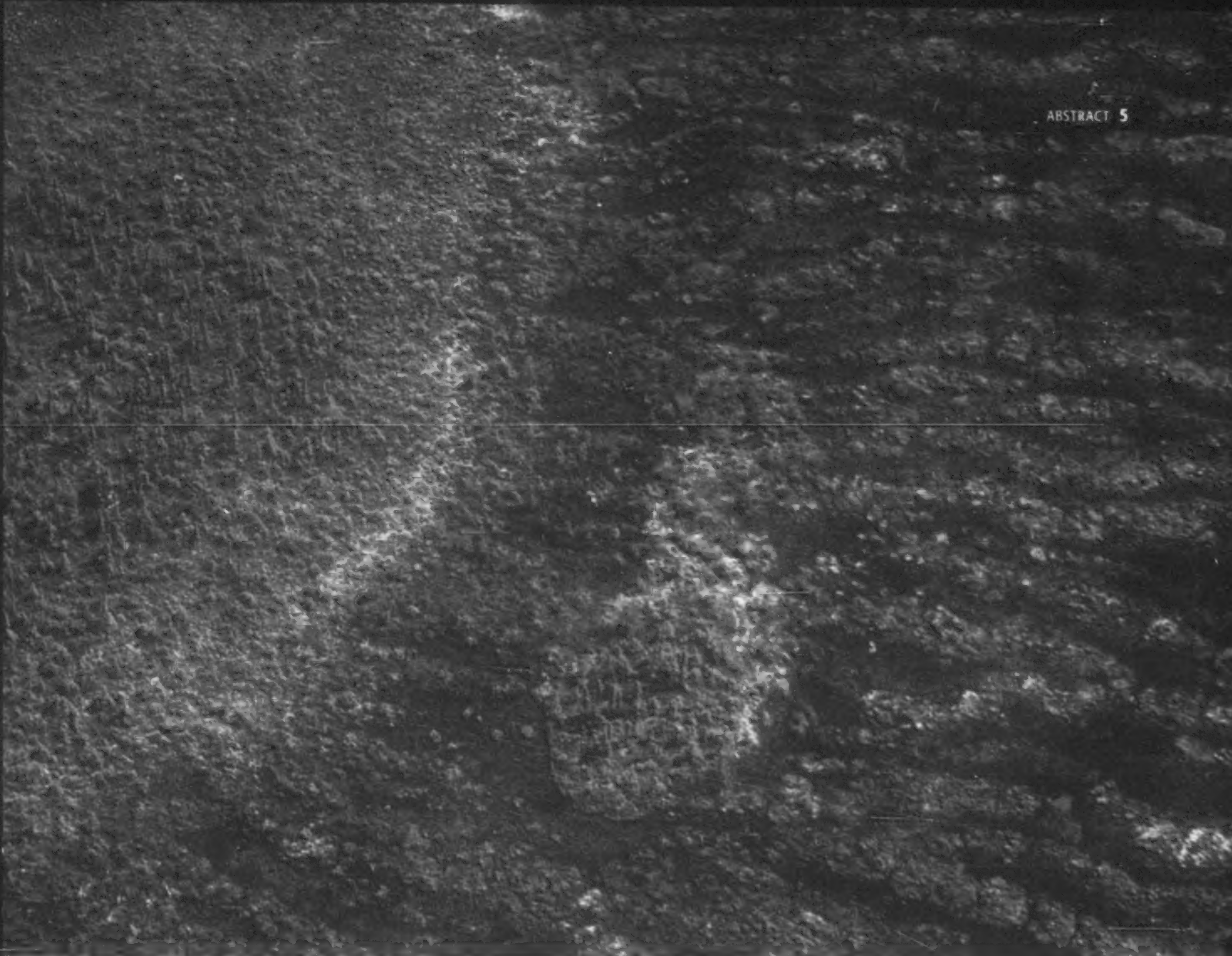


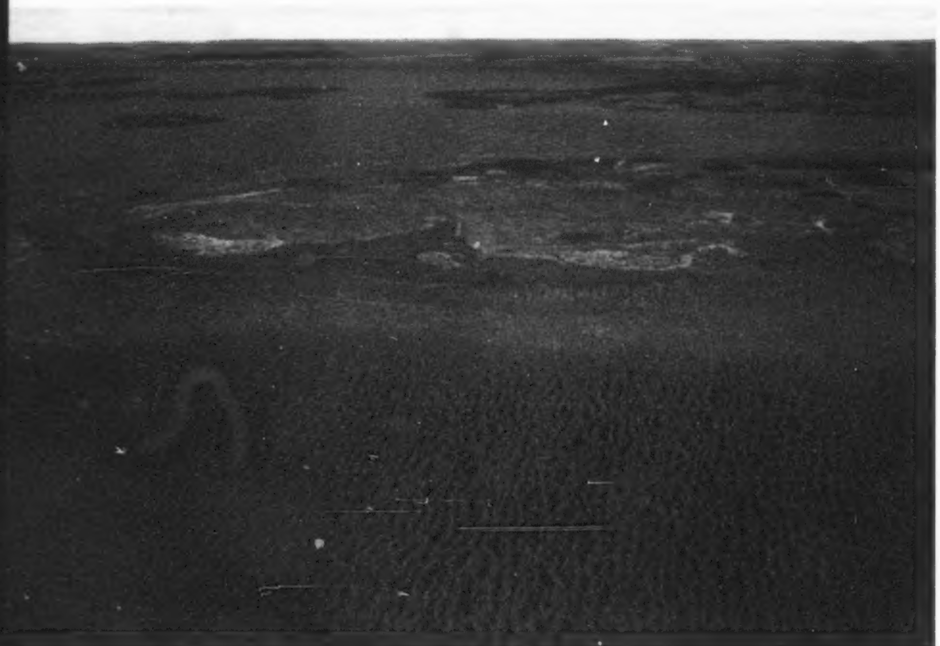
Bog on left, flanked by fen drainway on right transitional to open bog, southwest interior.

Abstract

The Hudson Bay Lowland (or Hudson Plain or Platform) supports the world's third largest wetlands, and the largest in North America. Eighty-three percent of this distinct geological province and ecozone lies in the Province of Ontario, Canada. The Lowland also lies at the core of the world's largest intact boreal landscape, and is one of the world's densest accumulations of peat, measurably cooling the global climate by sequestering atmospheric carbon.

More than 85% of the Lowland in Ontario is either mineral wetland or organic peatland, much of it underlain by permafrost and most of it untreed. Overall, it is a clay-based terrain of flat plains and moraines that emerged from the sea over the last 6000 years (and is emerging still), evolving an unparalleled array of bogs, fens, swamps and permafrost peatlands, and along its 1290-km ocean coast, the same flat gradients give rise to an incomparable breadth and range of intertidal and supratidal marshes.

The Lowland's ecological significance and the imminent pressures it faces for mineral and energy development, underscore the need for enhanced natural-resource knowledge in support of sound land-use decisions, community wellbeing and superior environmental assessments. This study focuses on the region's dominant wetland terrain and provides: a regional overview; descriptions of wetland types; analyses of ecological variation and succession; keys to wetland types; and a catalogue of summary field data.



Echoing River fens, western interior.

It incorporates published and unpublished surveys by numerous Lowland researchers and has at its core the original field data collected at;

- James Bay and Hudson Bay coastal wetlands from 1972 to 1976, supported by the Ontario Ministry of Natural Resources (OMNR) and Environment Canada;
- interior peatlands and wetlands from 1976-1990, supported by the Ontario Geological Survey, Royal Ontario Museum, OMNR, and Environment Canada; and
- Kinoje Lake area, central Attawapiskat River area, Aquatuk Lake area, lower and coastal Shagamu River area, and elsewhere (1972 to 1990), supported by Environment Canada, Royal Ontario Museum, OMNR, and others.

Field survey methods included standard quadrat and transect surveys of both mineral and organic (>30cm peat) wetlands. Rapid reconnaissances were made of large homogeneous site types, measuring species cover values, surface-water pH and temperature 10cm below surface water level, depth-to-water, peat depth, and substrate type. More than 300 of these relevees were later analyzed. The strongest vegetation ordinations were correlated with these measures, and with site elevation, distance from coast, latitude and longitude. The strongest correlations with vegetation variability were water pH (surrogate for nutrient status) and depth-to-water (surrogate for saturation and root aeration), which parallel the dominant successional themes and which inform an understanding of wetland patterns. Peat depths increase with distance from the coast, as peat accumulation exceeds peat decomposition. Water pH decreases with increasing peat depth and with increasing depth-to-water. The major successions are from marsh and meadow marsh (coastal), to fen and bog (interior), and to palsa and peat plateau (northward). These are complicated locally by multidirectional, cyclic and collapse sequences, such as ice formation and collapse, and water-flow changes, which elaborate on the major regional themes of succession.

General regional wetland descriptions and classification are summarized, building on Ontario past practice in wetland surveys and mapping, using a nested, hierarchical classification that applies at scales ranging from dominance-type relevees and habitat surveys, to regional remote-sensing and data roll-ups. The approach is based on vegetation composition and physiognomy, and catalogues six formations (swamp, marsh, meadow marsh, fen, bog, and peat plateau and palsa), as well as subformations, physiognomic groups (35), and dominance types and site types that are catalogued. Wetland succession is related to wetland variability, pattern, stratigraphy and permafrost, and is discussed both in general and for specific parts of the Hudson Bay Lowland.

Acknowledgements

The field surveys on which this overview is based occurred through the generous assistance of many agencies and individuals. The Ontario Ministry of Natural Resources (OMNR), and its former Centre for Remote Sensing and Forest Research Branches, and the current Ontario Parks, and the Canadian Forestry Service, Canadian Wildlife Service and Lands Directorate of Environment Canada provided field support. The individuals of these agencies extended to me great collegiality over the years in accessing the Lowlands, and I am most grateful to S. Pala, A.N. Boissonneau, R. Mussakowski and A. Jano, former Ontario Centre of Remote Sensing; J.K. Jeglum and R.A. Sims, Canadian Forestry Service; D.W. Cowell and W. Glooschenko, Lands Directorate,; R.K. Ross and R.I. Morrison, Canadian Wildlife Service; and N.T. Roulet, McGill University and Northern Wetlands Study (NOWES). Special thanks to Gabriel Fireman of Attawapiskat and Toby Hunter of Fort Severn for field support. Above all, I am indebted to John Jeglum for inviting me to join him as a student of peatlands, to Arthur Boissonneau for his geological insights, and Harry Lumsden for his early encouragements. Thanks to J.H. (Jock) McAndrews and D. Siddiqi of the Royal Ontario Museum for analysis of peat, pollen and spore from two sites, and dating. Finally, special thanks to the Nature Conservancy of Canada for supporting the completion of this study, and to the Royal Ontario Museum for supporting much of its original fieldwork and analysis.

The final preparation of this report was supported by the Far North Branch of OMNR, Rob Davis and Bill Crins of Ontario Parks, who continued the earlier encouragements of OMNR's Art Currie and Bill Ringham. Thanks as well to Bill Crins, Ontario Parks, and Wasyl Bakowsky, Ontario Natural Heritage Information Centre, for reviewing draft manuscripts. I am particularly grateful to Judie Shore for her report design and production.

Participation on the Ontario Far North Science Advisory Panel in 2009-2010 assisted greatly by challenging me to recall and re-learn aspects of the Lowland from different points of view. In this regard I would particularly like to thank Nigel Roulet, McGill University, for his expertise on the carbon dynamics of peatlands; Sean Thomas, University of Toronto, for his insight into boreal forest dynamics; Tim Lynham, Environment Canada, for his appreciation of wildfire ecology in the north; John Gunn, Laurentian University, for his hydrological perspectives; and Ken Abraham, OMNR, for sharing his experience regarding wildlife.

Many thanks to those who identified lichen and bryophyte collections: Christine Manville, University of Toronto; Robert Ireland, Linda Ley, I.M. Brodo, P.W. Wong, Canadian Museum of Nature (CANM); and Howard Crum, University of Michigan (MICH). Duplicate vouchers are in the author's collections.

Art Boisonneau and author in the field.

All photos by J.L. Riley except for photo above and on page 34 (left), by S.Pala.

Regional Overview

The dominant terrain of the Lowland is its spectacular patterned palette of coastal wetlands and interior peatlands, variably arrayed across a vast flat clay plain.

Open graminoid (net) fen, with 25% fen pools and ponds, and 25% treed permafrost fen ribs, central interior.

Dominating Canada's boreal latitudes are a quarter of the globe's wetlands and more than a third of its peatlands (Taylor and Smith 1980, Zoltai 1979, Gore 1983). Thirty years ago, in an era of concern for energy supply, Ontario's peat reserves were inferred to be in the order of 110 billion tonnes, equivalent to 70 billion barrels of oil, almost all in the Hudson Bay Lowland (Monenco 1981) (Fig. 1). Now, in an era of concern about greenhouse-gas emissions and climate change, the same Lowland peatlands are viewed as immense stores of carbon (more than 35GteC, gigatonnes equivalent carbon), much more than the rest of Ontario's natural ecosystems combined (FNSAP 2010; Roulet, Gray, pers. comm. 2009). Both of these modern interests contrast markedly with the prevailing opinion only fifty years ago, when Coombs was typical in his remarks about the "*physical unattractiveness of its terrain, a poor climate, and a lack of natural resources*" (1952).

Eighteen percent of Canada is wetland, of which three-quarters are peatland (NWWG 1988). More than 85% of the Hudson Bay Lowland Ecozone is covered by wetlands (Canada 1974).[1] Well over 90% of its 1290-km Ontario coastline is coastal marshland and meadow marsh (Glooschenko 1980a,b). However, the vast majority (more than four-fifths) of Lowland wetlands are peatlands, wetlands with more than 30 to 40cm of accumulated peat. The Lowland is part of the Far North of Ontario, and the Provincial Government has committed itself to conserve and protect more than half of the region, focusing on the benefits of its ecological services, including its biological diversity and its storage of carbon. (Ontario 2010).

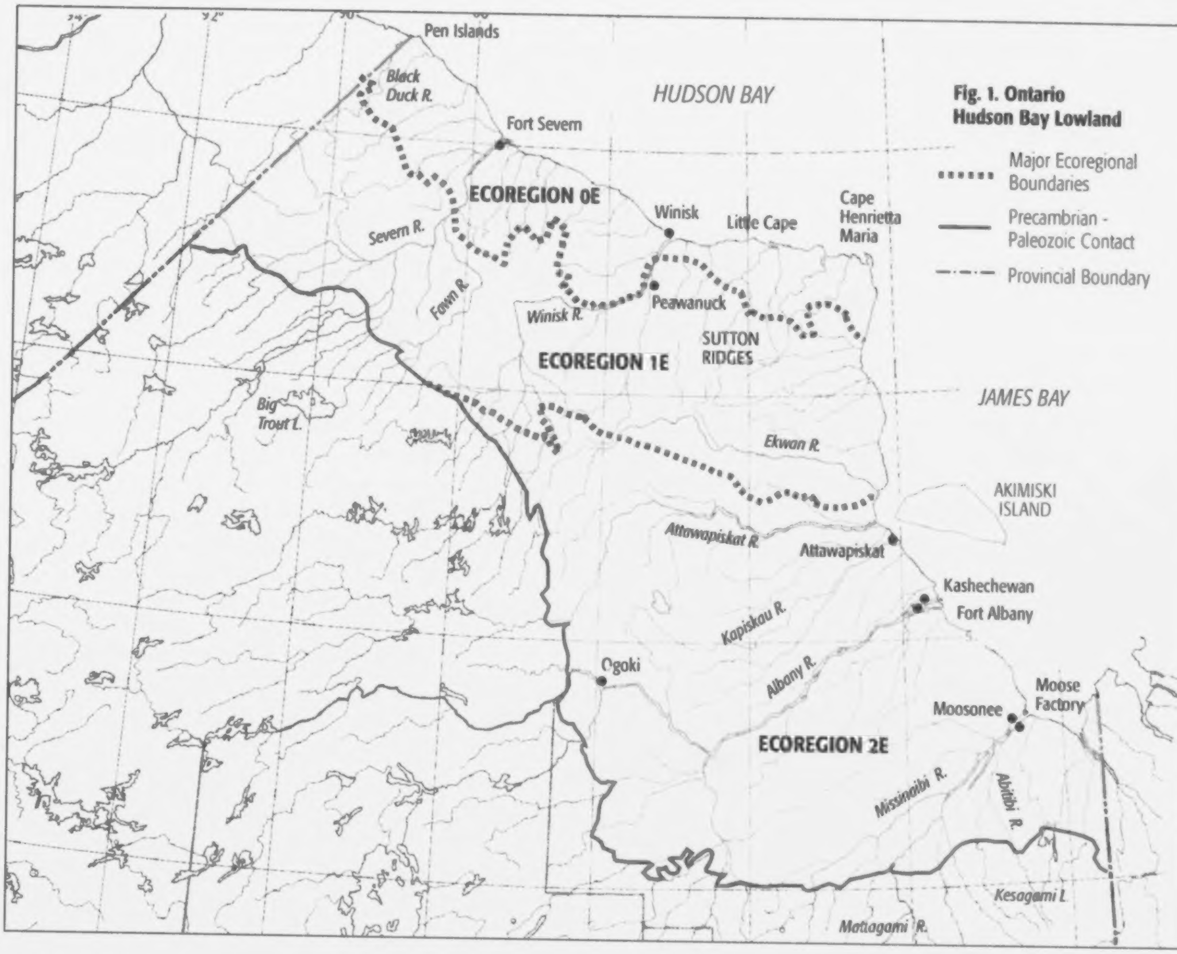
The dominant terrain of the Lowland is its spectacular patterned palette of coastal wetlands and interior peatlands, variably arrayed across a vast flat clay plain. Slowly, over millennia, peat has accumulated, from 1 to 3m+ deep, in habitats such as bog, fen, marsh, swamp and frozen palsa and peat plateau. The region experiences one of the globe's fastest rates of postglacial uplift (isostatic rebound) and, as it rises, the slope of the land flattens, thus retaining more water and peat (Gough 1998). Tree cover diminishes northward and coastward, from closed forests at the region's southern edge, along narrow treed river levees and rare uplands, down to a vague tree-line that tracks the Hudson Bay coast at a distance of 5 to 50km and more inland.

The extent of major habitats in the Hudson Bay Lowland

Estimated from satellite imagery, airphotos and field experience (Riley 1982, 1989). The Ontario Ministry of Natural Resources is currently updating these provincial land-cover estimates for the 250,000-km² region.

Water (lakes, rivers, ponds) 7%
Marsh (freshwater and tidal) 4%
Bog and fen 60%
Peat plateau, palsa and tundra 12%
Swamp, woodland and forest 15%
Rock barren, burn and Early regeneration 2%

Parallel beachridge swarms, with inter-ridge peatlands, inland from Hudson Bay.



GEOLOGY

More than a quarter of Ontario, in a broad band 150-300km wide, lies in the Hudson Bay Lowland. The Lowland is a Paleozoic (limestone) and partly Phanerozoic geologic province surrounded by the Canadian Shield.[1] The land is undergoing North America's fastest rates of isostatic rebound after its long depression by the Laurentide ice sheet, at rates up to 1.2m per century over the last 1000 years (Webber *et al.* 1970). The last millennium, for example, has revealed an estimated 30km-wide band of newly colonizable coast at Cape Henrietta Maria, this at a rate now much diminished from that of the immediate post-glacial period. The Lowland emerged above the postglacial Tyrrell Sea as it drained down to conform to the modern Hudson and James bays over the past 6000 years (Fig. 2; Webber *et al.* 1970; Andrews 1968,1970; Prest 1970). All of the Lowland emerged first as a dynamic tidal landscape, supporting mineral wetlands that gradually succeeded to organic peatlands as the land rose and the coast receded (McAndrews *et al.* 1982).

This emergence revealed sea-bottom substrates that are almost universally marine silts and clays, often to depth, but also deposited only shallowly on higher till moraines, such as between the Moose and Albany rivers, along the Manitoba border in the west, and on the slopes of the Sutton Ridges, the Precambrian outlier that intrudes above the Lowland in the Hawley, Sutton and Aquatuk lake area (Bostock 1971). Elsewhere, along river valleys and on sea-washed subglacial deposits and beachridges, there are also pockets of more permeable sorted materials but these too are usually veiled or underlain by strata of silt and clay.

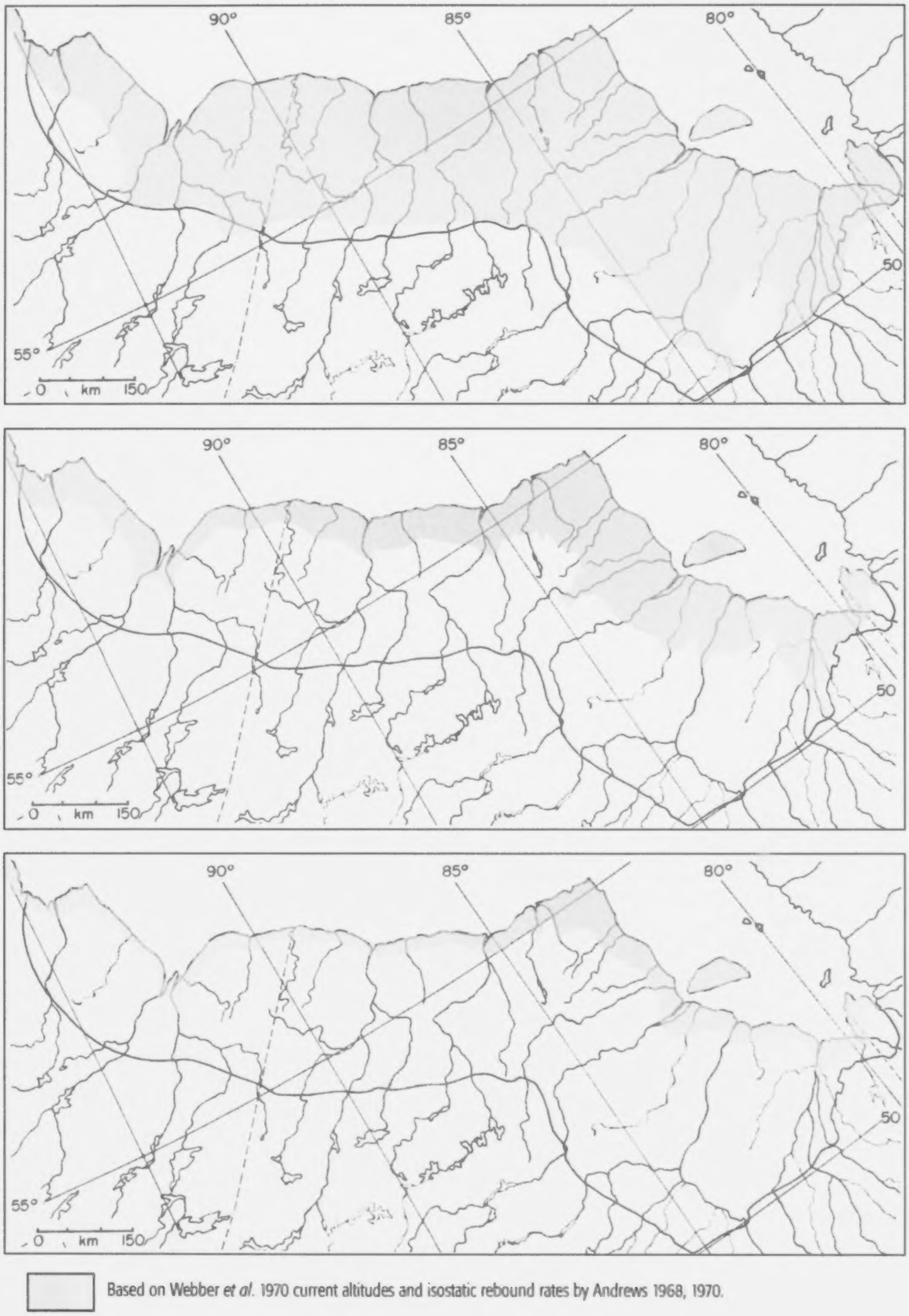
[1] 'Hudson Bay Lowland' corresponds to the geologic province of the same name (Norris *et al.* 1967, Sanford *et al.* 1968). Its geologic boundary is generalized as the Hudson Plain or Hudson Bay Lowland Ecozone (ESWG 1995, Crins *et al.* 2009).

Fig. 2 Emergence of the Hudson Bay Lowland from the Tyrrell Sea (Riley 2003)

a. ca. 5500 years BP

b. ca. 4000 years BP

c. ca. 2000 years BP



Based on Webber *et al.* 1970 current altitudes and isostatic rebound rates by Andrews 1968, 1970.

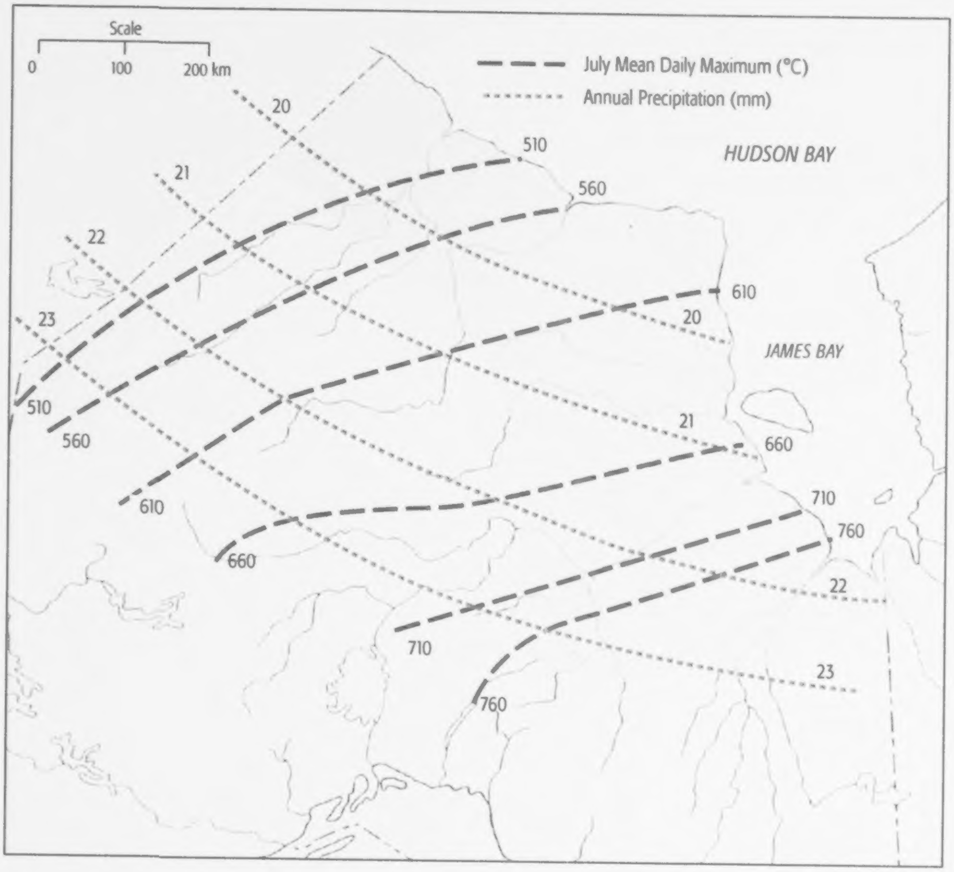


Fig. 3 General Climatic Trends

Precipitation and temperature isolines are generally at right angles to each other in the Hudson Bay Lowland, resulting in the strong regional gradients. The HBL becomes cooler south to north, and drier southeast to northwest (data from Chapman and Thomas 1968, Sims *et al.* 1979).

These predominantly impermeable substrates hold water on the surface and result in slow lateral drainage down almost imperceptible slopes (av. 65cm/km in the Moose River basin and 75 to 100cm/km from Big Trout Lake to Hudson Bay). Thus arose the uniquely large and inaccessible wetland and peatland ecosystems of the region, flourishing on a generally flat plain that is only slightly elevated above (but hydrologically distinct from) the other major hydrologic systems of the region, which are its downcut river valleys that drain some of Canada's largest rivers, like the Albany, Moose, Attawapiskat and Severn. It is along this separate, downcut drainage network, and along the ocean coasts, that more youthful, dynamic, mineral wetlands dominate.

In the immediate postglacial period, emergent areas were better drained by a steeper, pre-rebound topography, and were subject to the warmer and drier conditions of the Hypsithermal period (ca. 7200 to 4200 yBP (years Before Present; Terasmae 1968). The subsequent cooling of the climate and decrease in topographical gradient encouraged the expansion and current dominance of the landscape by wetland and peatlands, as much as 90% by some calculations (Ketcheson and Jeglum 1972). Such a "*sea of peat*" creates its own limiting environmental parameters by restricting nutrient availability and maintaining saturated conditions. This self-defining scenario is also influenced by the ability of *Sphagnum* to acidify water through the selective exchange of hydrogen ions for other cations (especially Ca^{++} and Mg^{++}) (Shotyk 1988).

Pre-flying surveys of the Lowland were largely the domain of geologists, beginning with Low and Bell of the Geological Survey of Canada in 1886 (Bell 1887), and followed by survey geologists Dowling, Wilson, Boyd and McInnes. A typical comment on conditions away from the rivers is Bell's note on the lower Attawapiskat: "*The Indians report the country as level and covered with sphagnum*" (*ibid.*:23). Rock exposures and timber were their focus, and these were on the levees and islands, so there was little motivation to trek inland. However, on behalf of the Ontario Bureau of Mines,

J.B. Tyrrell traversed the region in 1912-1913 and, in 1924, Hawley followed up Dowlings' 1904 surveys of the Sutton Ridges (Hawley 1925). Tyrrell summed up the situation: "*Great areas are...flat, and practically undrained, and such flat areas are now covered with peat bogs on which grow scattered forests of small stunted spruce and larch....All the evidence... pointed distinctly and conclusively to the fact that there are no rocky hills anywhere in* [the] *fifty-mile strip* [along Hudson Bay]" (1913:173). Other major ground-based surveys were botanical, by the Arctic Institute of the Catholic University of America in the 1950s and 1960s, led by Lepage, Dutilly and Duman (references *in* Riley 2003). These too were water-based surveys, with any reconnaissance of the interior wetlands still a rarity during the growing season.

CLIMATE AND PERMAFROST

The water and carbon regimes of the region are strongly influenced by its subarctic climate, as are its ecosystems and wildlife. The region's south and west are strongly influenced by the continental climate of the North American interior but Hudson Bay and James Bay strongly cool and moisten the lands nearer the coasts. These two waterbodies freeze in winter, and half the offshore waters in some places between Fort Severn and Cape Henrietta Maria can still be covered by ice in late July (Danielson 1971, Rouse 1991, Gagnon and Gough 2005a,b). The summer position of North America's Arctic Front is forced south by the cold of Hudson Bay (Bryson 1966), which generates persistent onshore summer winds and land-sea breezes that lower temperatures, increase fog and reduce evapotranspiration rates. Similar maritime climates occur on the coasts of Labrador and the Aleutians, also the result of cold offshore waters. The cool, moist climate contributes to the rapid growth and longterm stability of wetland and peatlands.

Climatic trends are illustrated in Table 1 for two Lowland stations, compared with their nearest interior station on the Canadian Shield to the south, and Toronto (Fig. 3; see Mortsch 1990).

A widespread effect of climate is the occurrence of permafrost in the northern two-thirds of the Lowland (Fig. 4; Brown 1969, 1970, 1973; Zoltai 1974). Permafrost occurs in bedrock, soils and peat, but peat is the superior thermal insulator and conserves frost most effectively; the southern limit of near-sea-level permafrost occurs, continentally, in the peatlands of the James Bay lowland. Permafrost systems include, in mineral soils and rocklands, tundra- and ice-wedge polygons, stone circles, ice-laminated river levees, and frost boils. Permafrost systems in peatlands include palsas (raised mounds of expanded peat) and coalesced palsa fields (peat plateaus), thermokarst lake plains and, southward, treed bog islands and open pools.

Within 100km of Hudson Bay, permafrost underlies most landforms, and it extends north under the bay. Permafrost systems have an *active layer* in summer, a depth of thaw that permits plant growth and water flow and retention. Palsas and peat plateaus have active layers up to 35cm deep in summer, overlying 3m or more of frozen peat. Southward lies a zone of discontinuous permafrost, with more isolated features, such as palsas, peat plateaus and treed bog islands (Cowell *et al.* 1978). South again, such as in the Albany River basin, permafrost features are less frequent, and they are generally absent from the Moose basin. Seasonal frost (rather than permafrost) can occasionally persist from year to year based on local conditions; for example, the cold summer of 1918 had ice persisting through August within 1.1m of the surface as far south as Kapuskasing (Kirkconnell 1919).

Raised permafrost peatlands are frequently dominated by lichens, and their high light reflectance (albedo) helps maintain cold subsurface temperatures. Wildfires can remove lichen cover, lower albedo, and deepen the summer active layer. Climate warming and increased fire frequency can have similar effects, collapsing frozen terrain and levees, increasing runoff and erosion, and releasing stored carbon as emissions. Along Hudson Bay, permafrost deterioration is also exacerbated by overgrazing geese, a physical rooting that also reduces surface albedo and increases thaw.

Table 1. Climate Norms (CSMB 1974, EC 1981)

	Mean daily temperature (°C)	Annual growing degree days >5°C	Mean annual precipitation (mm)	Annual days with precipitation
Winisk	-5.5	625	608	164
Big Trout Lake	-3.0	1025	581	161
Moosonee	-1.1	830	728	173
Cochrane	-0.6	1300	885	149
Toronto	7.3	2300	762	137

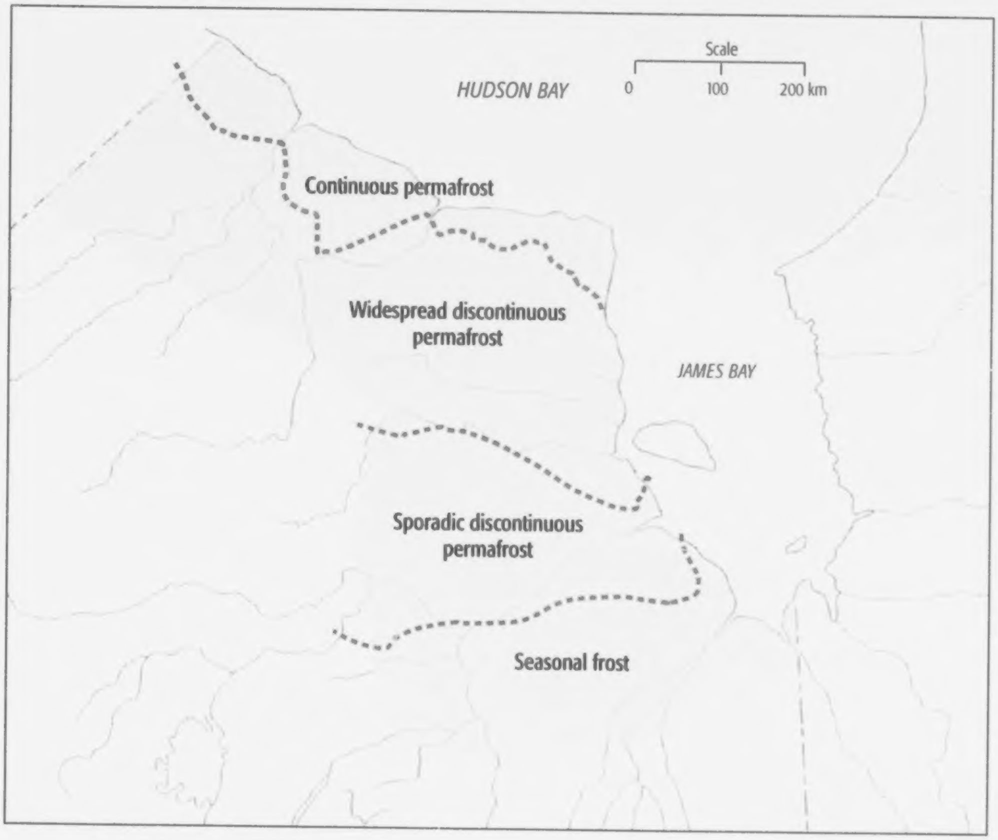


Fig. 4. Distribution of Permafrost

(Refer Fig. 20; and Benson 1973)

CARBON STORAGE

The peatlands in Ontario's Hudson Bay Lowland store as much carbon as all the other natural ecosystems of Ontario combined, likely in excess of 35 GteC, and sequestering about 3M tonnes annually (Roulet, Gray, pers. comm. 2009). The amount sequestered annually is equal to about a third of Ontario's current total carbon emissions (Gray, pers. comm., 2009). The Lowland is one of the Earth's major carbon storehouses, and there is growing documentation of the role that peatlands play in cooling the global climate. Change in its capacity to store or sequester carbon may result in unpredictable longterm effects. Climate change and human activities can alter wetlands, effect storage regimes, and release carbon to the atmosphere.

About a tenth of the globe's cooling benefits from peatlands comes from Ontario's Hudson Bay Lowland (Roulet, pers. comm, 2009). Northern peatlands as a whole cover about 3 to 5% of the land area of the globe but they store about 25% of all terrestrial carbon (Gorham 1991). These are some of the globe's highest carbon densities, and the Hudson Bay Lowland is one of the densest of these concentrations, in the order of more than 150 to 200 kg/m^2 (Tarnocai *et al.* 2009). This is two to three times greater than the carbon stored in upland boreal forest or tropical rainforest. Estimates of current carbon accumulation in this region range between ~20 and 30 g Cm^2/ m^{-2} yr^{-1} (Gorham *et al.* 2003).

Peat depths vary in the Hudson Bay Lowland; bogs average 2.2m and, where they are frozen into peat plateaus closer to Hudson Bay, they average more than 3m (App. B). Fens are shallower, averaging 1.8m deep. The unparalleled scale and patterns of these interconnected surface waters, wetlands and peatlands attracted scientific attention to the Lowland as early as the 1960s, research that was fundamental to the understanding of Canada's wetlands (Sims *et al.* 1979).

Peat accumulates where primary production exceeds decomposition because oxidation is limited by resident water. Water also limits the diffusion of oxygen into the peat, resulting in less efficient anoxic decomposition, which stores carbon but also produces methane, a greenhouse gas.

If the water table in a peatland is close to the surface or if a peatland is dominated by plants such as sedges that can transport methane through the upper unsaturated–oxic zones of a peatland (*e.g.*, wet graminoid fens), then methane emissions can range from 2 to 30g CH_4-C m^{-2} yr^{-1}. Some estimates suggest that northern peatlands account for ~10% of the total atmospheric burden of methane, as much as 30% of all natural sources (Denman *et al.* 2007).

Some peatlands are a net source of methane to the atmosphere, but others are an even more significant sink for carbon dioxide, another greenhouse gas. The storage of sequestered carbon is maintained in peatlands over thousands of years, long after a peatland's methane emissions have equilibrated with atmospheric concentrations of methane. Where peatlands are older than 300 to 500 years (*i.e.*, succeeded to *Sphagnum* domination), as is the case with most peatlands in the Hudson Bay Lowland, then the sequestered carbon results in a net radiative cooling. This 'two-gas' role of peatlands — a sink for carbon dioxide but an emitter of atmospheric methane — makes them a unique ecosystem (Mortsch 1990). Methane is a more powerful radiative greenhouse gas than carbon dioxide but it has a much shorter atmospheric lifetime. Thus, methane is important in the short-term (<100 years) but the carbon dioxide sink is much more important in the long term (>300–400 years) (Frolking and Roulet 2007). Both gases must be considered in models that predict the carbon functions of peatlands, and different peatland types may function differently. At present, peatlands in the Lowland are a major net sink of carbon dioxide and a moderate source of methane emissions (Roulet *et al.* 1994).

In 1990 the Northern Wetlands Study measured emissions of methane, carbon dioxide and non-methane hydrocarbon along a 100km transect from Kinoje Lake to North Point (Klinger *et al.* 1994). They concluded that the "*seasonal flux* [of emissions]*...and...net primary productivity...show systematic change along a successional sequence...consistent with patterns predicted from successional theory....Given this, it is likely that models of carbon trace gas flux based on succession models may be useful in predicting climate change-landscape change feedbacks.*" (*ibid.*) In order to develop such models for landscape change and successional sequences, standard vegetation terminology and mapping must be achieved at regional scales.

CLIMATE CHANGE

Even in the absence of industrial development in the region, Lowland ecosystems will change as the climate warms (Colombo *et al.* 2007, EPCCA 2009). In the past fifty years, precipitation has increased in the region and average air temperatures have risen by 0.3 to 0.4°C. While tundra bird populations are as yet unchanged (Cadman *et al.*2007), Polar Bear are losing weight (M.Obbard, pers. comm. 2009), and sea-run Brook Trout (Charr) have died in warmed waters (Gunn and Snucins 2010). Freeze-up is coming later, and break-up earlier, over the past few decades (Gough *et al.* 2004). It is predicted that, by 2050, temperatures and precipitation in the Hudson Bay Lowland will have increased enough to alter plant communities, degrade permafrost, lower water levels in lakes, rivers and wetlands, reduce ice cover on land and sea, and affect fish and wildlife and forest growth. While specific outcomes remain unpredictable, it is generally agreed that there has been no previous experience with such rapid rates of change.

The largest predicted temperature rise is for winter months, especially along the Hudson Bay coast. Hudson and James bays are the world's largest, cold, inland seas and they have major effects on regional and continental climate and weather. Reduced ice cover may result in increased solar warming (reduced albedo), warming the water in Hudson Bay. Precipitation along the coastlines of Hudson and James bays is also predicted to increase and, as with rising temperatures, the major effect is predicted to occur in winter.

Changes in water levels in peatlands (positive or negative) alter the ecological functions of wetlands, such as storage, sequestration, emission, cooling and habitat. Small changes in temperature may also have significant effects on snow cover and thaw depth (Maxwell 1992). Palsas, peat plateaus, tundra, ice-aggraded river levees and thermokarst lakes may be particularly susceptible. There are already visible collapse and accretion features across the Lowland, but it is not yet known to what degree they are associated with climate change. It is also difficult to predict the implications of these changes for the release of greenhouse gases (compare Tarnocai 2006, Dorrepaal *et al.* 2009, Laine *et al.* 1996), but the sensitivity of peatlands to water-level changes warrants caution regarding land uses and development that alter water flow or storage.

The impacts of climate change on northern forests are also unpredictable. Growth of boreal trees generally shows a positive trend with higher temperatures in the historical record (*e.g.*, Briffa *et al.* 1995) but, beyond particular thresholds, there are also documented temperature-related growth declines (*e.g.*, Barber *et al.* 2000). Negative impacts may also include drought stress on boreal trees, increased fire frequencies, and increased forest pests and pathogens.

Climate-envelope models have also predicted changes in forest composition (Malcolm *et al.* 2005).

Peatlands have been characterized as complex adaptive systems (Hilbert *et al.* 2000, Belyea and Baird 2006). Synergistic feedbacks in peatland systems can result in stable, self-regulating interactions between hydrology and peatland growth, resulting in positive carbon storage. However, it is not clear that these self-regulating mechanisms will be sustained at the predicted pace of climate change. As well, other as-yet-unforeseen forces may offset some other predicted impacts. For example, while global sea levels have risen about 0.2m in the past century (and are likely to rise three times as much in the next century), this predicted rate of sea-level rise is less than the present rate of postglacial uplift on the Lowland coast, so that sea-level effects on coastal wetlands may be less in the Lowland than elsewhere.

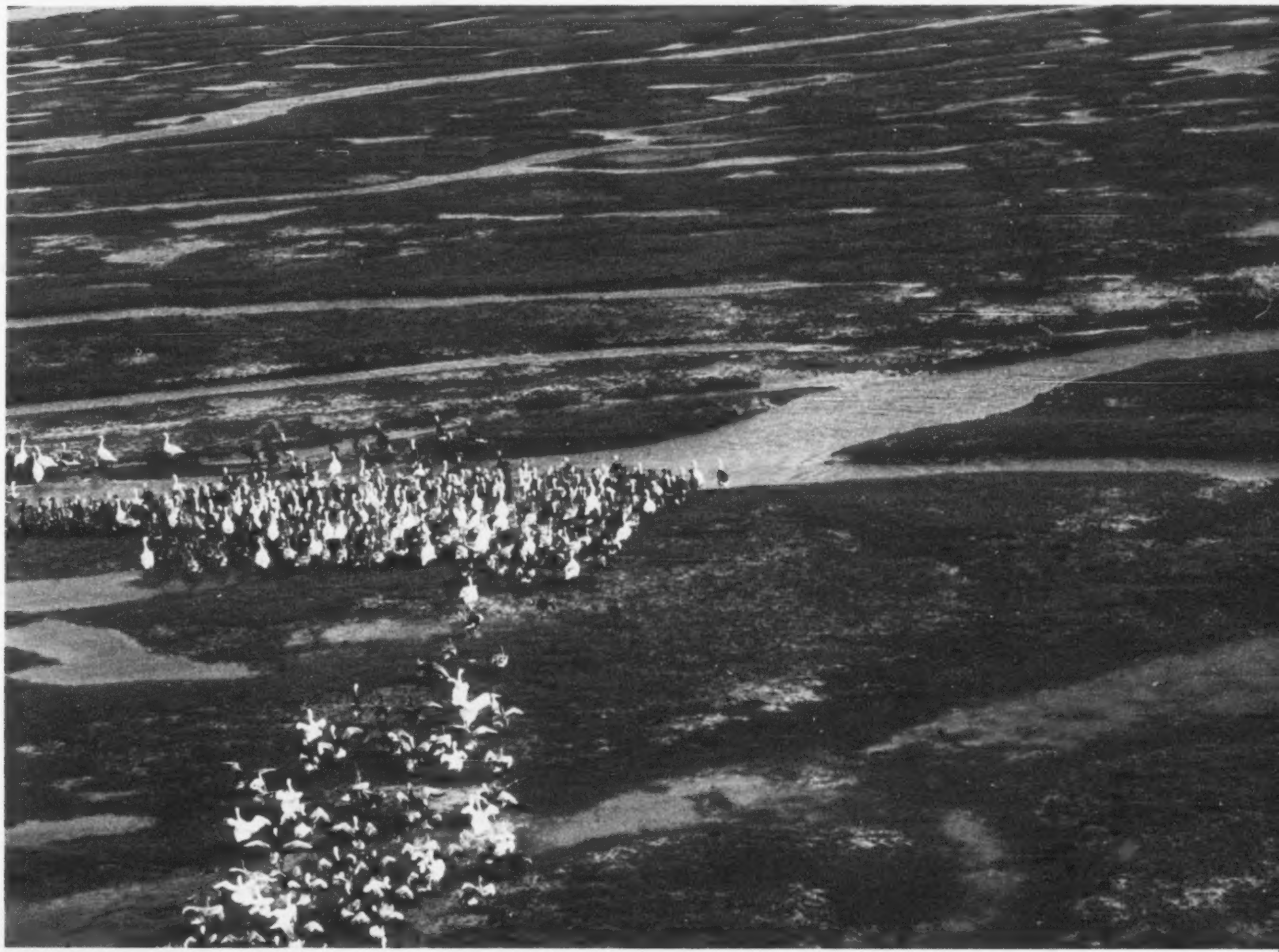
BIOLOGICAL DIVERSITY

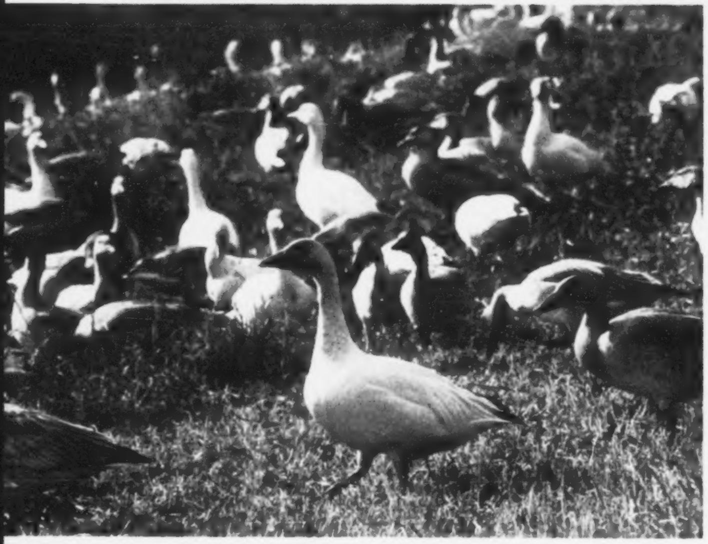
Wildlife remains abundant in the Hudson Bay Lowland and is of economic and cultural importance to its residents, who have relied on it for millennia. After European contact, species depending on wetlands and peatlands, such as beaver, caribou and marten, were significantly reduced in numbers. Some of the migratory birds that breed in, or migrate through its wetlands were also harvested heavily, here and elsewhere, reducing shorebird numbers in particular. In modern times, most species, such as beaver and marten, have recovered strongly, while others have not (Stewart 1981, Lytwyn 2002). The reliance of Lowland residents on fish and wildlife has remained strong, almost 100g of wild protein per adult per day in 1990 (Berkes *et al.* 1994, 1995).

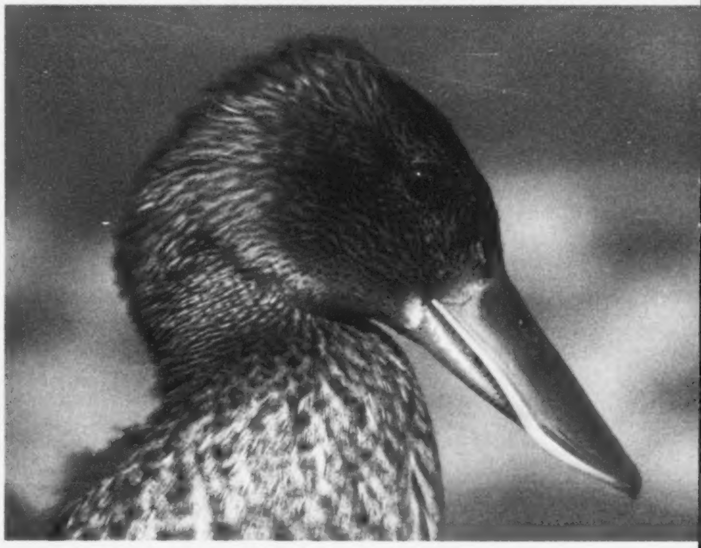
The Hudson Bay Lowland supports two types of caribou, the dispersed boreal-forest ecotype in its southern two-thirds, and the migratory tundra ecotype along Hudson Bay. The two of them mingle to some extent in the winter but the tundra caribou gather to calve along the coast, and the forest type disperses widely to calve in the interior (OMNR 2009). Current caribou numbers are not limited by the availability of its preferred lichen-rich habitats, such as lichen-dominated peat plateaus, beachridges and treed bogs, and old-growth woodlands (Ahti and Hepburn 1967).

TOP. Caribou, Pen Island foreshore, 1978.

BOTTOM. Polar bear lounging on coast, Cape Henrietta Maria area.







OPPOSITE TOP and BOTTOM LEFT. Snow Geese, Cape Henrietta Maria.

OPPOSITE BOTTOM RIGHT. Northern Shoveller, mouth of Shagamu River.

LEFT. Semipalmated Sandpipers, southwestern James Bay coast.

The Lowland is at the core of North America's primary boreal breeding nursery for landbirds, and Ontario shares a continental responsibility with its neighbouring boreal jurisdictions for these birds, whose numbers migrating south each fall have so far remained relatively constant (BSC 2003). For migratory waterfowl and shorebirds, the coasts of James and Hudson bays provide the only tidal saltwater habitats between the maritime arctic and the Gulf of St. Lawrence and the Atlantic and Gulf of Mexico. Its coastal wetlands are also one of North America's primary breeding and nursery landscapes for waterfowl and shorebirds (Hanson and Smith 1950, Raveling and Lumsden 1977, Martini *et al.* 1980, Thomas and Prevett 1982, ESTR 2010). Large portions of the continental populations of Brant, Lesser Snow Goose and Canada Goose make use of these habitats, and the tidal marshes of Ontario are of hemispheric importance for at least fourteen species of shorebirds in both the early summer and fall, including the endangered Red Knot and subarctic specialists such as Hudsonian Godwit and Whimbrel. The funnelling effect of Hudson Bay and James Bay coastlines, which concentrate birds spectacularly during fall migration, is of global significance and remains one of North America's few examples of its former faunal abundance (Wilson and McRae 1993). The entire coast has been designated as Important Bird Areas, based on the high proportions of global and continental populations of birds.

Wildlife abundance can reflect distant circumstances. For example, the dramatic increases in the Snow Goose and Canada Goose are the result of over-feeding (due to the availability of grains) on their southern wintering grounds (Snow Geese), and of restored resident populations in eastern North America (Canada Goose). These increases have resulted in aggressive waterfowl grubbing in coastal wetlands, destroying their own preferred habitats, and these external forces offer no respite, and no time for rejuvenation (Abraham and Jeffries 1997, Kotanen and Jeffries 1997, Jeffries *et al.* 2006).

Invertebrates are "*poorly studied*" in the Lowland (Shorthouse *et al.* 2003), despite their critical role for avifauna and for ecological processes in general. A single study of saltmarsh insects at North Point, James Bay, found 318 species, at least eight of them new species (Kakonge *et al.* 1979). Mosquitoes and biting flies seem to dominate the invertebrate biomass; the former have been estimated at some 12,700,000 per hectare on parts of the Hudson Bay coast (West 1951). The wetland mollusk *Macoma balthica*, gastropod *Hydrobia minuta*, and both larval and adult flies are among the critical understudied food sources for shorebirds like the Hudsonian Godwit and Red Knot, as well as the spectacular flights of Semipalmated Sandpiper (Martini *et al.* 1980).

Regional Wetland Variability

Wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of shallow marine water

(Ramsar Convention 1971).

An ancient tamarack fen now succeeded to open *Eriophorum* bog, southwest interior.

Wetland vegetation is by definition adapted to water and provides distinctive habitats for dependent biota. Wetlands can be either mineral, in close contact with underlaying substrates, or organic, with more than 30 to 40cm of accumulated organic material or peat. *Peat* is a word of ancient origin, in English use before 1200 and even earlier in Celt (*pette*) and Anglo-Latin (*peta, petamore*; OED 1971). A wide use of the term peatland has emerged in reference to terrain dominated by organic wetlands.

In the northern hemisphere, descriptive terms are both ancient and varied. The Algonquian term *muskeg* described open, untreed peatlands, and was later applied to peatlands in general, both open and treed. The Russian *taiga* broadly described the saturated terrains of sparse conifers and peatlands in the boreal north. Northern Eurasia has similar flat, marine-clay plains that also emerged from arctic seas as the result of postglacial uplift of the land, and Fennoscandians used terms like *aapamoore* to describe their northern boreal string bogs and patterned fens, *palsamoore* for subarctic permafrost peat mounds and plateaus, and *arktische/moore* for their maritime peatland tundra (Moore and Bellamy 1974). *Moor* is the German equivalent of the English *mire* (Norman *myrr*; Swedish *myr*) and is another term (like *muskeg*) whose generality of application has reduced its usefulness in describing specific wetland types (Jeglum *et al.* 1974).

Early Europeans also used a variety of terms to describe wetland types more particularly, and these were organized in the 1800s, and consolidated across Fennoscandia in 1913 by A.K. Cajander, who distinguished 35 types based largely on their botanical and physiognomic character. This has been the prevailing approach since, complemented by a variety of scale-based and user-based approaches, some of which have been applied to Canadian wetlands, with varying usefulness on landscapes like the Hudson Bay Lowland.

LANDSCAPE SCALES

Some of the early characterizations of the Lowland at the scale of landscapes were based on limited information about the region and limited field surveys. They include, from north to south:

- *Tundra, forest tundra, open woodland (taiga), close forest* (forest regions, Hustich 1949; Hare 1950, 1954);
- *Forest tundra, muskeg woodland, main boreal forest* (forest regions, Coombs 1952);
- *Subarctic, hemiarctic, northern boreal, mid boreal* (vegetation zones, Ahti 1964);
- *Forest tundra, open woodland, closed forest* (bioclimatic zones, Hare and Ritchie 1972).

A common assumption was that terms that had been developed to describe terrestrial ecosystems were appropriate to this unique wetland ecozone. This reflected the lingering impression, based on early river-based geological and timber surveys, that general terms like *muskeg* and *swamp* would suffice, without further specifics (*e.g.*, Bell 1887, Ontario 1900, Miller 1912). Similarly, the early literature on the development of Ontario peat for fuel offered no discrimination among wetland types (*peat bogs*: Ells 1882; Anrep 1914, 1921; Auer 1930).

LEFT. Inter-ridge permafrost (net) fen, northwest interior.

MIDDLE. Open graminoid (net) fen, with treed permafrost fen ribs, central interior.

RIGHT. Open graminoid fen, with pools and treed bog islands, 10km inland from James Bay south of Kapiskau River.

Subsequent studies of trafficability, engineering, wildlife and ecology introduced new terms;

- trophic regimes; *ombrogenous* (rain-based), *topogenous* (catchment-based), *soligenous* (flow-based) (Sjörs 1950);
- waterfowl habitat; *timbered muskeg, open muskeg, lake-land muskeg, pothole muskeg, smallpox muskeg* (Hanson and Smith 1950);
- muskeg engineering; *marbloid* and *reticuloid* (northward) and, as well, *stipploid* and *dermatoid* (southward) muskeg types; Radforth 1969).

The advent of aerial photography finally documented the dominance of the region by wetlands, and invited new airphoto classifications. Brokx (1965) conducted the first pattern-based sub-regional mapping. Landscape units were mapped, even while acknowledging that dominance patterns varied, and that one any type could contain other types. Terms describing the dominant patterns included, from north to south: *tundra, forest tundra, muskeg, lichen woodland, lichen muskeg, bog islands, spruce muskeg* and *fen, wet bog, tamarack fen, raised bog, bog*, and *transitional forest* (Brokx 1965). Based on this sub-regional classification, Bates and Simkin (1969) interpreted airphotos to a map-scale of 1:633,600. They introduced additional terms to those of Brokx, including: *palsa bog, palsa fen, palsa field* (= plateau), *polygon fen, lichen heath, sedge meadows* and *black spruce forest* (=swamp). Together, these works established the range of terms that continue in use today to bridge both landscape and site-type scales in regional wetland studies.

At landscape scales, a series of wetland types was also developed to reflect variation in terrain morphology (*palsa, peat mound, plateau, thermokarst*), pattern (*net, ribbed/ string, ladder, collapse, polygon*), landscape position (*flat, horizontal, channel, slope*), tidal position (*coastal, estuarine*), and proximity to water bodies (*floodplain, stream, channel, basin, shore*) (Tarnocai 1980, NWWG 1988). Keys to these types in Ontario were developed by Riley and Michaud (1994; and see below, Wetland Succession, Vegetation Patterns, Pattern Types).

The site-type approach of Cajander and the later researchers who applied it, strongly influenced the wetland classification system proposed for Ontario in 1974 by John Jeglum, Art Boissonneau and Vic Haavisto, *Toward a wetland classification for Ontario*. In summary, they said, "*Since the physiognomy and dominance patterns of vegetation express the resultant of all the transactions within a wetland ecosystem, we have used these vegetation patterns to define wetland types....We can* [thus] *add physiographic relationships...to the wetland types as descriptive adjuncts.*" By this means, wetland descriptors could be applied accurately at the field level and be aggregated up-scale in a hierarchical manner, and could thus be associated with other data collected at different scales.

This classification was tested for field use and for interpreting airphotos and satellite imagery in the 1970s in the Northern Clay Belt (*ibid.*), in the Groundhog River peatlands southwest of Timmins, and in the Kinoje Lake area northwest of Moosonee (Jeglum and Cowell 1982, Sims *et al.* 1982). On this basis, the Ontario Geological Survey applied the approach to its mapping of the surficial geology of the Hudson Bay Lowland from 1976 to 1979 (Pala and Boissonneau 1982, Pala and Weischet 1982, Riley 1982), and in the Ontario Peatland Inventory (1982-1986), which mapped and classified peatlands at scales ranging from 1:10,000 to 1:100,000 over study areas covering 207,000km^2 of Ontario (Riley 1988, 1989, 1994a,b; Riley

and Michaud 1989, 1994). The hierarchical nesting of classification units was critical to using it at scales ranging from supervised classification of satellite imagery to detailed vegetation relevees, and for rolling-up and extrapolating site-specific environmental and chemical variables across broader landscape-scales.

Environment Canada used the same approach in its ecological land classification in the Lowland (Cowell *et al.* 1979). As well, the Province of Ontario's *Planning Act* requires the evaluation of wetlands in land-use planning (OMNR 2009), and the wetland evaluation systems for northern and southern Ontario apply this approach to classifying and mapping wetlands (OMNR 1993a,b).

Finally, wetland regions have been described for Canada (NWWG 1988) and the Hudson Bay Lowland (Riley 1982). These are paired below with their ecoregional equivalents (Ontario - Crins 2002, Crins *et al.* 2009; Canada - ESWG 1995); and described more fully below (see Ecoregional Wetland Characteristics):

- Ecoregion 0E (Hudson Bay Coast) (ESWG ecoregion 215) (humid high subarctic, SHh)
- Ecoregion 1E (Northern Taiga) (ESWG ecoregion 216) (low subarctic, SL)
- Ecoregion 2E (James Bay) (ESWG ecoregion 217) humid high boreal, BHh)
- Ecoregion 3E (Lake Abitibi) humid mid-boreal, BMh)

Open (stipploid) graminoid fen, southwest interior.

THE MAIN VARIATION AT FIELD SCALES

Hydrology

The major discrimination among wetlands in the Hudson Bay Lowland is between mineral and organic wetlands. Across the Lowland, these are also indicative of distinct hydrological systems. The hydrological system that supports mineral wetlands is dominated by marsh, meadow marsh and swamp, and is comprised of streams, ponds, rivers, lakes and coasts. Effectively, this is the immediate drainage system of the Lowland, and its waters are uniformly in contact with mineral substrates, which confer a richer nutrient status on such systems. This hydrological system grades, in some areas, into organic systems, such as along rising elevation gradients away from the coasts, where mineral-rich marsh grades slowly into fen and swamp as peat-depths increase.

The other hydrological system, which supports organic wetlands, consists of peats that, by comparison, seal their surface waters from substrate contact and thus limit nutrient availability. This peatland hydrological system has limited surface flow, most notably in the spring melt, and very slow water percolation laterally through peats that have different permeabilities, based on peat type. Effectively, this is the water storage system of the Lowland. It is dominated by bog, fen and swamp, and northward, by permafrost peatlands (palsa, peat plateau), all of which blanket the dominant clay plain of the region as well as its till-based uplands and its closed basins.

Patterns and Geomorphology

As noted above, the patterned wetlands of the Hudson Bay Lowland have astonished fieldworkers and have given rise to many descriptive terms that, while working for specific purposes, fail to meet the test of replicability of application (*viz.*, Bates and Simkin 1969, Radforth 1969, etc.)

Hugo Sjörs undertook his seminal studies on Canadian wetlands in the Hudson Bay Lowland (1959, 1961, 1963). In 1959 he noted, "*The strange patterns...are more difficult to interpret than the features themselves.*" The scale of the patterns makes them even more daunting; "*The percentage of peatland in relation to total land area in the middle and northern parts of the Hudson Bay Lowland is so close to 100% that it could scarcely be higher anywhere in the world*" (1963). He described the relationship of patterns to topography, flow and peatland succession: "*Succession in peatland includes much more than the normal succession starting in a wet habitat that are described in ecological text books*" (1961b). He used examples

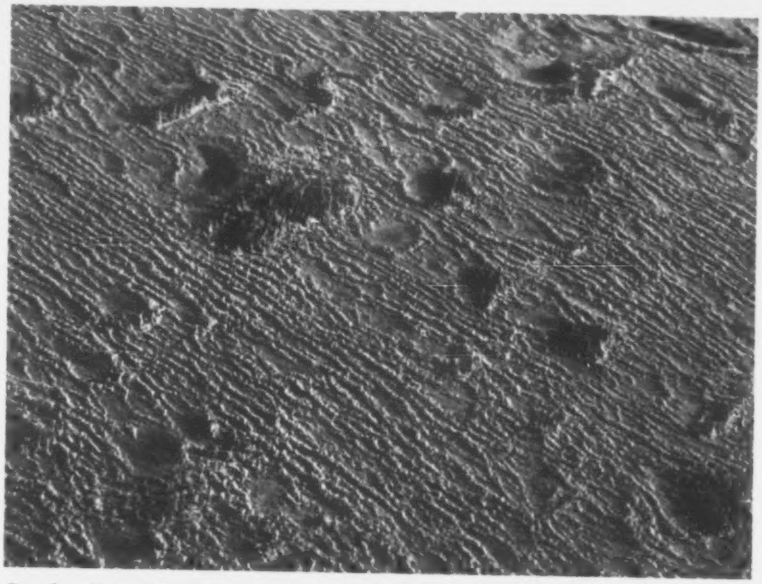
WETLAND CLASSIFICATION

Canadian wetland classifications at different geographic scales and for divergent purposes have been reviewed by Jeglum *et al.* (1974), Sims *et al.* (1979), Zoltai *et al.* (1975, 1988). A consensus was developed by the National Wetlands Working Group (NWWG 1988) applying a hierarchy of three levels:

1. **CLASS.** Based on the overall genetic origin of the wetland ecosystem; BOG, FEN, MARSH, SWAMP, WATER, PALSA/PEAT PLATEAU
2. **FORM.** Based on location, pattern and geomorphology; *e.g.*, Raised, String, Seepage, etc.
3. **TYPE.** Based on vegetation physiognomy; a finer-scale variability reflecting nutrient status and, less so, regional climate and substrate; *e.g.*, Lowshrub, Graminoid, etc.

Wetland classifications that were extensions of this approach also employed a level 4, Dominance Type or dominant vegetation, based on averaged dominance of multiple relevees (Jeglum *et al.* 1974, Zoltai *et al.* 1975, Riley and McKay 1980). An additional quantitative level 5, or Site Type, based on specific site relevees, was also applied to reflect Hill's approach (1959, 1976), applied in phytosociological treatments developed to characterize wetland diversity by ecoregion (Maycock 1979).

The approach here employs levels 1, 3, 4 and 5, above, expanding on the classification for Ontario wetlands developed by Jeglum *et al.* 1974. The same approach is used to organize descriptive keys and summaries of wetland types (App. A,B), and the catalogue of regional wetland types (App.C). This conforms with past practice, but two other major classification approaches warrant cross-walking in support of consistency: the International Classification of Ecological Communities (ICEC; Grossman *et al.* 1998); and Canadian Vegetation Classification (CVC; NVWG 1990, Ponomarenko and Alvo 2001).



Open fen with treed ribs and bog islands, northcentral interior.

Wetland Classification		ICEC (1998)	CVC (2003)
FORMATION (= CLASS)	*e.g.* BOG	CLASS	I
Subformation	*e.g.* OPEN		
Physiognomic Group (=TYPE)	*e.g.* LOWSHRUB	FORMATION	IV
Dominance Type	*e.g. Chamaedaphne calyculata*	ALLIANCE	V
Site Type	*e.g. Sphagnum* spp.– *Chamaedaphne calyculata*	ASSOCIATION	VII

This approach has been tested and applied at multiple scales, using different classification levels for different applications, and thus permitting regional roll-ups, extrapolation of results, nested map units, etc.;

FORMATION Multiple scales; from vegetation sampling to interpretation of remote sensing

Subformation Same multiple scales

Physiognomic Group Vegetation sampling, peat inventory, habitat descriptions, data rollup

Dominance Type Vegetation sampling, habitat descriptions

Site Type Field data collection, environmental variables, instrumentation, etc.

This approach to wetland classification also supported the 1981 identification of representative, candidate nature reserves in the Ontario Hudson Bay Lowland (Riley 1981).

such as black spruce islands in fens; the pools scattered in large bogs and fens; patterned *flarks* (Sw., terraced hollows or pools) separated by elevated ridges (of treed or untreed bog or fen); and treed palsas. He later noted other complicating patterns, like wooded fens and riparian fens (1963).

Overall, peatland patterns reflect underlaying topography and surficial and ground water flow. The lower and wetter elements tend towards minerotrophy (fen) and array themselves either parallel to or perpendicular to flow direction. The higher and drier elements tend towards more ombrotrophic conditions and are most often bog, and mark either raised surfaces or elevation breaks. The patterns of pools in bogs and fens, and their coalescence into larger waterbodies, are even less well understood, and they suggest successions that are antithetical to textbook examples of peat infilling depressions. Sjörs used the term "*polyclimax*" to describe the various directional and reversal successions that are coincidentally occurring within a particular wetland complex, generating distinctive patterns (1961). These processes also occur in permafrost wetlands, where succession by ice accretion and degradation can occur simultaneously in close proximity, in both raised palsa systems or in flat thermokarst lake systems. There are also similar patterns in shallow coastal peatlands, which are reflected in particular vegetation types there, with the same patterns in deeper interior peatlands, but with different vegetation.

No attempt is made here to classify wetland patterns in the Hudson Bay Lowland but, rather, to identify the constituent vegetation comprising those patterns, and outline the successional trends underlying particular patterns. Close instrumentation of the variability of vegetation and environmental conditions across particular patterns, over time, are absent from the Lowland, but parallel research in peatlands in northern Europe are relevant, for example, studies indicating particular patterns can persist over millennia (Moore and Bellamy 1974).

A working list of general wetland patterns (geomorphological types) of wetlands is included below (Wetland Succession, Vegetation Patterns, Pattern Types), but it is by no means inclusive. Such descriptive terms are used primarily in airphoto interpretation and in coarse-scale remote sensing but, in a region of unparalleled variability in wetland patterns, these non-hierarchical descriptors have, to date, proven to have limited field use or roll-up capability (*e.g.*, the 96 classes mapped by Bates and Simkin 1969), as compared with vegetation classification.

Nutrient Status and Vegetation Variability

Sjörs noted that classification was a practical necessity but that "*the classification of peatlands and their vegetation is, in any case, somewhat arbitrary*" (1961a). He discussed previous approaches, noting that the term peatland had the least confusing connotations, and he defined the nutrient status and vegetation of Lowland peatlands for the first time: bog, fen, swamp and palsa/peat plateau. He emphasized the nutrient gradient from strict *ombrotrophy* (nutrients available more or less solely from precipitation and air-borne nutrients), to *minerotrophy* (nutrients available from underlaying or transported mineral substrates as well as from precipitation). He nominated nutrient classes relevant to the Hudson Bay Lowland, annotated here with their trophic and vegetation equivalents, based on surveys in the Hawley Lake area (1961a) and the Muketei River area (1963):

- Oligotrophic: pH equal to or less than 5.2; ombrotrophic to weakly minerotrophic; *e.g.*, bog, peat plateau/palsa, and poor fen;
- Mesotrophic: pH 5.2 to 7.0+; minerotrophic; *e.g.*, moderately rich fen, conifer swamp;
- Eutrophic: pH more than 7.0; strongly minerotrophic; *e.g.*, extremely rich fen, marsh, swamp.

Sjörs tested these classes at descriptive scales, and documented the changes in vegetation composition that paralleled the changes in nutrient availability.

This combination of vegetation and nutrient status has formed the basis of subsequent wetland classifications, with the emphasis shifting over time from trophic terms to their vegetational equivalents, and to terms incorporating both physiognomy and composition, such as those developed by Cajander (1913, 1926), Sjörs (1961a, 1963) and Jeglum, Boissonneau and Haavisto (1974).

More detailed analysis has shown these to reflect primary environmental gradients: 1) moisture-aeration regime; and 2) nutrient-pH regime (Jeglum 1973, 1974). Moisture-aeration is measured as depth of water or depth-to-water, a surrogate for the level of saturation of the rooting zone, the availability of oxygen to roots, and the resultant suitability of sites to variously hydrophytic species. Nutrient-pH regime, in this case the measurement of surface-water pH, is an indicator of the varying amounts of nutrient that are available to the vegetation. A more general term for low pH, or acidity, would be "*base neutralizing capacity*," or the ability of acidic natural waters to neutralize nutrient cations and make them unavailable to vegetation (Shotyk 1988).

Major Formations

PEAT PLATEAU AND PALSA

Fennoscandian origins (Sami *balsa*, Swedish *palse*, Finnish *palsa*); Russian equivalent (*bugor*). Use in Canada advanced by Radforth (1955) and Sjörs (1959, 1961b) etc.

Continuous permafrost dominates within 60 to 100km of the Hudson Bay coast, where palsas and peat plateaus dominate. Permafrost becomes discontinuous southward (both areally and stratigraphically), and effectively disappears south of a line from the south end of James Bay westnorthwest to the Manitoba border at about 92°W. In the zone of discontinuous permafrost, more southern elements like treed bog islands, peat mounds and pools transition into discrete palsas elevated by ice expansion, and this elevation further dries and acidifies these elements. North again, palsas occur with increased frequency, and coalesce into raised permafrost peat plateaus whose characteristic physiognomy is of 1) a raised frozen hummock phase (palsas),with 2) interstitial hollows between the hummocks (Railton and Sparling 1973, Brown and Kupsch 1974). These extensive permafrost peatlands are similar to bog in their vegetation, except for the predictable dominance of the raised phases by lichens, particularly *Cladina*. They are sporadically patterned with ice-wedge polygons in the area inland from Cape Henrietta Maria and the Brant River. Between the Winisk and Shagamu Rivers, and elsewhere, the continuous peat plateaus support thermokarst lake systems. The frozen peat under these peat plateaus is 3 to 4m thick (>3.6 ± 0.8, n=3), with ice continuous into the underlaying substrates. Active layers average 25-45cm deep and their raised, dry conditions make them the most fire-susceptible of wetland types.

Over large areas southwest of Cape Henrietta Maria and south of the Pen Islands, there occur frozen peat plateaus that are also raised but without hummock-hollow phasing and with shallow, wet active layers 10 to 20cm. These are dominated by moss and graminoid species typical of open bogs or fens, and these tundra wetland types are included in the catalogue (App. B) as open permafrost bogs and fens. *Tundra* is a term of Lapland origin, first used in English in 1841 in reference to northern Siberia (OED 1971); tundra wetland types are not treated as a distinct formation here but warrant closer study of their variability in the Lowland.

TOP. Permafrost peat plateau, with thermokarst lake, inland from Little Cape, Hudson Bay.

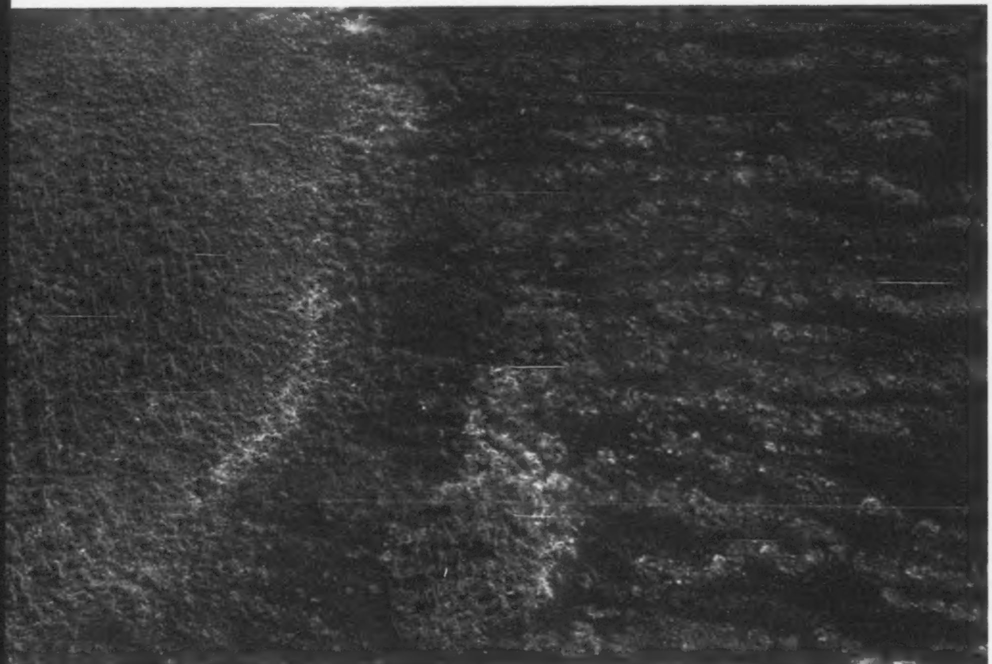
BOTTOM. Shallow pond in open tundra fen, 6km inland from western Hudson Bay coast.

Subformations

OPEN	Less than 10% cover by trees >135cm tall
TREED	More than 10% cover by trees >135cm tall (10-40%; trees >10cm DBH <10%)

Physiognomic groups

LOWSHRUB	Shrubs 20-135cm tall dominant, >10% cover
DWARF SHRUB	Shrubs <20cm tall dominant, >10% cover
LICHEN-RICH LOWSHRUB	Lichen dominant, >45-50%; low shrubs >10%



BOG

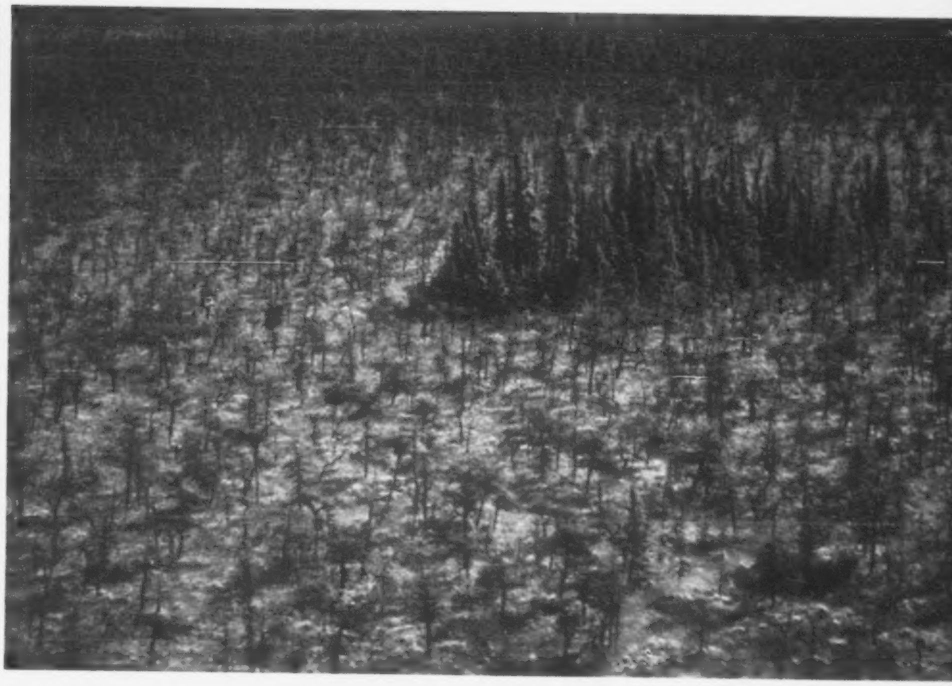
From the Gaelic and Irish, first recorded in English use in 1505 (OED 1971).

Bogs are peat-covered plains or peat-filled depressions with a high water tables and a surface carpet of mosses dominated by *Sphagnum*. The moss often forms raised hummocks intersected by low hollows, and the water table, at least in the hollow phase, is at or near surface in the spring, though below surface for the drier times of the year. In flat or level bogs, the water may remain at the surface throughout the summer. In either case, the surface waters and peat waters are isolated from mineral soil waters, strongly acid, and deficient in mineral nutrients. The peat is deposited *in situ* under restricted or contained drainage, and is dominated surficially by fibrous, acidic *Sphagnum* peat. Bogs are predictably dominated by *Sphagnum*, with black spruce, ericaceous shrubs and a few adapted sedge species present. Bogs differ from fens in the reduced availability of nutrients to the surface vegetation, and in their extremely low species diversity. (After Zoltai *et al* 1974, Jeglum *et al.* 1974, Riley and Michaud 1994, NWWG 1988.)

Bogs can also be effectively dry wetlands, and average depths-to-water can predictably exceed those of other wetland types (Fig. 18). Bogs throughout the Lowland are variously free of permafrost or with either continuous or discontinuous permafrost; peat depths in ecoregions 0E and 1E average >1.8m (± 0.6, n=33), and in ecoregion 2E average >2.6m (± 0.8, n=124).

Subformations	
OPEN	Less than 10% cover by trees >135cm tall
TREED	More than 10% cover by trees >135cm tall (10-40%; trees >10cm DBH <10%)
Physiognomic groups	
SHRUB-RICH	Shrubs >135cm tall dominant, 10-30 (40)% cover.
LOWSHRUB	Shrubs 20-135cm tall dominant, >10% cover
DWARF-SHRUB	Shrubs <20cm tall dominant, >10% cover
LICHEN-RICH LOWSHRUB	Lichen dominant, >45-50%; low shrubs >10%
GRAMINOID	Graminoids dominant; >10% cover
SPHAGNUM	Sphagnum dominant; shrubs, graminoids <10% cover
POOL	Small waterbodies within bog

TOP LEFT. Bog on left, flanked by fen drainway on right transitional to open bog, southwest interior.



FEN

From Old English, German and other languages, and first recorded in English use in Beowulf, which was written between 650 and 750 (OED 1971). The term was early associated with peat wetlands interspersed with pools and drainways.

Fens are peat-covered sloping plains or channels with very high water tables and with surface carpets of brown mosses and associated *Sphagnum*. The mosses usually form uniform, flowing patterns with minor hummocks and hollows reflecting flow patterns in their changing physiognomy. Fens have very high water tables, usually with evidence of lateral surface flow or seepage, and with average depths-to-water less than 20cm even at the driest times of year. They are predictably dominated by richer floristic assemblages of sedges, low shrubs, grasses, reeds, tamarack, cedar and orchids. Fens can range from weakly acidic to strongly minerotrophic, especially the latter in sites experiencing groundwater discharge from adjacent uplands and thus supporting strong marl development. Fen peats are dominated by weaker mosses and dominant graminoids and shrubs, thus taking on a laminated structure (where there is >50% sedge peat), which permits both internal expansion or contraction to stabilize effective water levels, and internal lateral flow of water. (After Zoltai *et al* 1974, Riley and Michaud 1994, NWWG 1988.)

Fens are wetter than bogs (Fig. 18), and are more variable in water nutrients, peat types, and species composition. Fens in ecoregions 0E and 1E are variously free of permafrost or with either continuous or discontinuous permafrost. Permafrost is rare in fens in ecoregion 2E. Peat depths in ecoregions 0E and 1E average >1.4m (± 0.7, n=31), and >2.2m (± 1.1, n=76) in ecoregion 2E.

Subformations

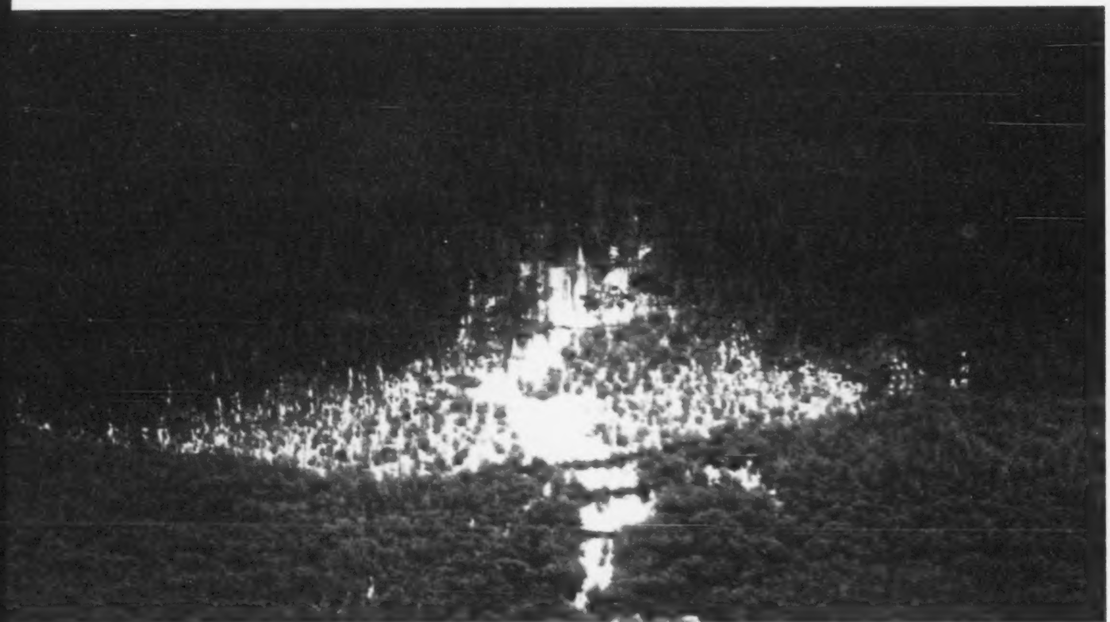
OPEN	Less than 10% cover by trees >135cm tall
TREED	More than 10% cover by trees >135cm tall (10-40%; trees >10cm DBH <10%)

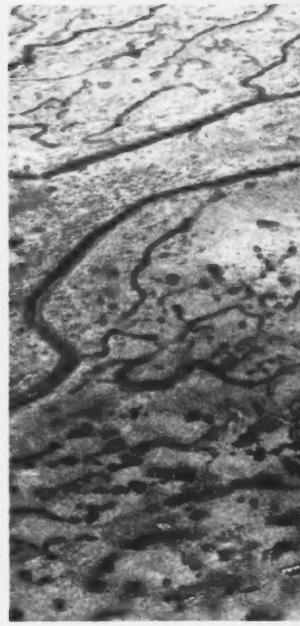
Physiognomic groups

SHRUB-RICH	Shrubs >135cm tall dominant, 10-30 (40)% cover.
LOWSHRUB	Shrubs 20-135cm tall dominant, >10% cover
DWARF-SHRUB	Shrubs <20cm tall dominant, >10% cover
GRAMINOID	Graminoids dominant; >10% cover
SPHAGNUM	Sphagnum dominant; shrubs, graminoids <10% cover
POOL	Small waterbodies within fen, usually patterned

MIDDLE. Patterned fen, of pools terraced with treed ribs, southwest interior.

RIGHT. Low-density tamarack fen, with treed spruce bog islands.





SWAMP

Likely of local Germanic and English origins, first recorded in relation to rich-soil North American (Virginian) wetlands by John Smith in 1624, as *"cypress, river or cane swamps"* (OED 1971).

Swamps are minerotrophic, nutrient-rich wetlands that are heavily wooded or with dense shrub thickets over 2m tall. Swamps often have hummocky surfaces broken by wet interstitial hollows (conifer swamp) or spring-flooded pools (broadleaf or thicket swamp). Along rivers, substrates can be of transported mineral or organic materials, but such riparian (broadleaf, thicket) sites are relatively infrequent in the Hudson Bay Lowland in comparison with organic (conifer) swamps. There is pronounced internal water movement through swamps, and broadleaf and thicket swamps can dry out completely in summer. The surface waters of the more predominant conifer swamps can be weakly acidic, less than pH 6.0, or they can be more alkaline in groundwater seeps and marl beds, and in sites dominated by tamarack, cedar and broadleaf trees and shrubs. With increasing acidity and wetness, conifer swamp grades into treed fens and bogs. Surficial peats underlaying conifer swamps are usually dominated by wood (>50%), and both living and peat mosses are more minor elements. Thicket swamps can also be transitional, occupying site gradients between open wetlands and drier or upland sites; or they can be successional, indicating regenerating former swamp sites or areas with altered water levels, such as beaver ponds. (After Zoltai *et al* 1974, Jeglum *et al.* 1974, Riley and Michaud 1994, NWWG 1998).

TOP. Thicket swamp foreground, conifer swamp background, Akimiski island.

RIGHT. Lichen-rich tamarack swamp, Moose River basin.

Physiognomic groups

CONIFER	Conifer trees dominant, >25% cover
BROADLEAF	Broadleaf deciduous trees dominant, >25% cover
THICKET	Trees <25% cover, shrubs >135cm tall >25%

MARSH and MEADOW MARSH

From Old English, Dutch and German; first recorded in English use in 705 (OED 1971).

Marshes are mineral wetlands or peatlands that are periodically or continuously inundated by standing or slowly moving waters, and associated with the open waters of streams, rivers, lakes and maritime shores. Surface waters fluctuate at least seasonally, such as in spring flood or ice-scouring of river meadow marshes after breakup, or as much as twice daily by tides. Water drawdown (again either seasonally or tidally) normally exposes matted organic or mineral substrates. Peats can be mixtures of marl, moss, sedge and wood peats. Such mixed peat substrates can have well more than 25% ash (mineral) content. Marsh is normally dominated (>25%) by emergent sedges, grasses, cattails or reeds, or low shrubs or ferns, interspersed in shallow waters or wet substrates. Denser, drier, semi-terrestrial types are termed meadow marsh. Surface-water calcium and magnesium levels are notably higher than in other wetland types. (Adapted from Zoltai *et al* 1974, Jeglum *et al.* 1974, Riley and Michaud 1994, NWWG 1988.)

Subformations

COASTAL	Within marine (salt) influence of Hudson and James bays
ESTUARINE	Subject to tidal reach, influenced by freshwater of major rivers
FRESHWATER	Beyond marine influences, mainly interior

Physiognomic groups

COASTAL and ESTUARINE	
INTERTIDAL	Subject to regular tidal water and ice influences
SUPRATIDAL	Above regular tides, subject to rare high tides
FRESHWATER	
SHALLOW	Emergent cover 75-100%, water <1m deep
DEEP	Emergent cover 25-75%, water can be >1-2m deep
SHRUB-RICH	Shrubs >135cm tall dominant, 10-30 (40)% cover
LOWSHRUB	Shrubs <135cm tall dominant, >10% cover

ABOVE CENTER Intertidal coastal marsh, southwestern James Bay.

ABOVE RIGHT. Supratidal meadow marsh, mouth of Moose River.

WATER

Usage following that of National Wetland Working Group (NWWG 1988).

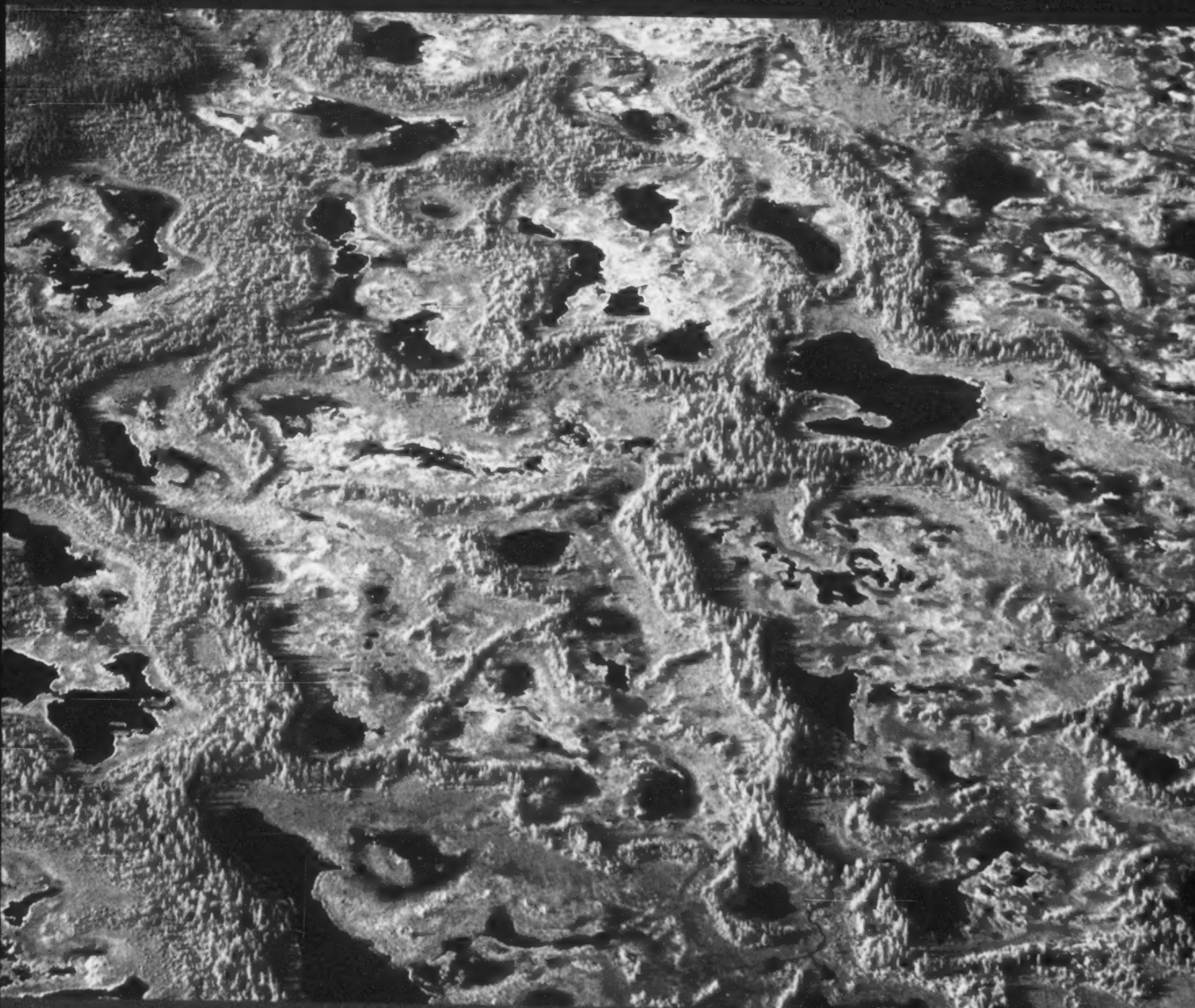
Deep and shallow waters up to 2m or more, are usually associated with flowing or standing waters in lakes, rivers, ponds or depressions between beachridges, for example. They are vegetated with sparse or dense floating, submergent or partially emergent vegetation, but usually have at least 75% surface water showing. In still-water situations, organic materials can be deposited that are non-fibrous and even colloidal (muck) in structure; these kinds of peats are often found underlaying mature fens or bogs, indicative of their open-water origins. Deep and shallow water pools differ from bog and fen pools in their diversity, their connection to mineral substrates and their minerotrophic status.

Physiognomic groups

SHALLOW	Standing water up to 2m deep, emergent or submergent vegetation
DEEP	Standing water >2m deep, primarily submergent vegetation

TOP. Deep water, shallow water and marsh at Pledger Lake, southern interior.

BOTTOM. Inter-ridge ponds, Shagamu rivermouth area.



Sampling Methods

Fen complex, with incipient palsa formation (ribs and mounds), in northcentral interior.

LEFT. Author and RIGHT, Art Boissonneau.

Vegetation Sampling

The reported surveys of the Lowland's organic peatlands were predominantly of selected homogeneous site types (with exceptions noted), while the reported surveys of mineral wetlands, along its coasts and streams, rivers, lakes and ponds, were predominantly transect-based. Both approaches have in common that they applied equivalent percentage-based, cover-value measurements at fixed sample points.

MINERAL WETLANDS

A. Coastal southwest James Bay (1972 to 1976; Riley and Moore 1973; McKay and Arthur 1975; also Ringius 1980). Surveys in 1972 and 1974 documented 22 vegetation transects (14km in total) oriented from low-water to high-water, recording cover, frequency and stratification (160 1m x 10cm plots in 1972 on 5 transects at Shipsands Island; 850 1m x 1.5cm and 0.5m x 0.5m plots along 17 transects at Shipsands and Puskwuche Point). In 1976 reconnaissances of intertidal and supratidal systems were conducted at Arnold Point, North Point, Longridge Point and Puskwuche Point. For these surveys, the identified dominance types refer to homogeneous communities covering hundreds of hectares, either in continuous or in mosaic-like patterns. Species-area curves were calculated in some cases as an index of homogeneity. These dominance types are summarized by Riley and McKay (1980), and catalogued here (App C). Beyond these major types is a wide range of heterogeneous, minor associations.

These plot data were augmented by subsequent reconnaissances northward:

B. James and Hudson Bay coasts (August 1976), transects at Fog Point, Lake River, Little Cape, coast west of Winisk, etc.;

C. Attawapiskat River (1977, Cowell and Riley 1978), quadrat sampling of riparian wetlands;

D. Lower Shagamu River (1977), ridge-pond-ridge transects, quadrat series;

E. Coastal surveys within 20km of the coast (1990, Wilson 1990), quadrats.

ORGANIC WETLANDS

Peatlands were surveyed by the author on a variety of quantitative and reconnaissance studies in the Lowland. The summary data on most frequent site types is included in the site catalogue (App. C).

A. Regional quantitative peatland sampling (2-28 July 1978 and 22 July-14 August 1979). This major helicopter reconnaissance of the Hudson Bay Lowland by the former Ontario Centre for Remote Sensing mapped the surficial geology of the Lowland for the Ontario Geological Survey. Because the region's surficial geology is predominantly organic, wetland data were collected to characterize large sites of homogeneous types, to identify signature reflectance values for supervised classification of LANDSAT imagery.

About 1600 sites were pre-selected from airphotos and LANDSAT imagery, and about one quarter of these were visited in the course of about 32,000km of flying at altitudes <500m. Two hundred and one sites were sampled (Fig. 5), many for more than one dominance type. A total of 309 of these vegetation samples had complete data sets that were subject to quantitative ordination (below). Sampling sites were the result of a combination of random and subjective site selection (see Riley and Michaud 1994), which was the general approach taken for all the quadrat surveys cited here.

At a site, the vegetation of the dominant homogenous type was sampled. The dominance types were characterized in the field, with only minor reconsideration later (App. C):

Formation	No. samples	% samples
PEAT PLATEAU/PALSA	4	<1%
BOG	166	54%
FEN	127	41%
SWAMP	2	<1%
MARSH	10	3%
Subformation		
OPEN	255	82.5%
TREED	54	17.5%
Physiognomic Type		
Shrub-rich	10	3.2%
Lowshrub	102	33%
Graminoid	167	54%
Sphagnum, Pool, WATER	30	9.7%

For comparison, the current estimates of the areal extent of peatlands in the Ontario Lowland are: peat plateau/palsa 22%, bog 36%, fen 24%, swamp 13%, marsh 4% and water 7% (Riley 1982, 1988). The proportion of sampled sites differs from this, and focuses on the most abundant, diverse and inaccessible systems, specifically the patterned and non-treed (open) bog and fen systems. Field surveys also avoided oversampling more predictable dominance types, such as treed lowshrub bog, treed lowshrub fen, conifer swamp and peat (bog) plateau.

At sample sites, 1m x 1m quadrats were thrown in areas of dominant homogeneous vegetation. In patterned systems (more than one type), data were collected for individual types, such as those arrayed as hollow, hummock or pool phases. Cover values were recorded for all vascular plant species (2 to 100%, and P=present for species less than 2%), and for moss and lichen species over 5% cover. In this rapid reconnaissance, only 1 or 2 quadrats were completed at most sites, although up to 10 quadrats were completed at others. Quadrat cover values were adjusted by assessing species presence and cover values over a 10m x 10m area of the same dominance type, as an expedient double-check on the cover values of dominant species. It also permitted a fuller record of the presence of all vascular plant species in the broader sample area, which would otherwise have required many quadrats to obtain comparable species-presence data, valuable because of species with high habitat fidelity at low cover values, in habitats such as fens. Balancing the sampling shortcomings of this reconnaissance method was a strict consistency of approach maintained at all sites, by a single individual, assuring comparability of results.

Also recorded at each site were average height, diameter-breast-height (DBH, and cover values of tree species attaining tree habit (>10cm DBH), and average height and cover values for each shrub species (woody species >15 cm tall). With the latter, particular note was made of the cover of shrub species (and trees suppressed at shrub size) that were less than 135cm tall (BH).

These plot data were augmented by numerous quadrat, transect and reconnaissance studies by the author employing the same data-collection approach:

B. Onakawana (1972, Stanfield *et al.* 1972), quadrats, transects and mapping;

C. Kinoje Lake (Kinosheo Lake) transects and plots (1976, Riley and McKay 1980); and quadrats, transects, mapping (1990);

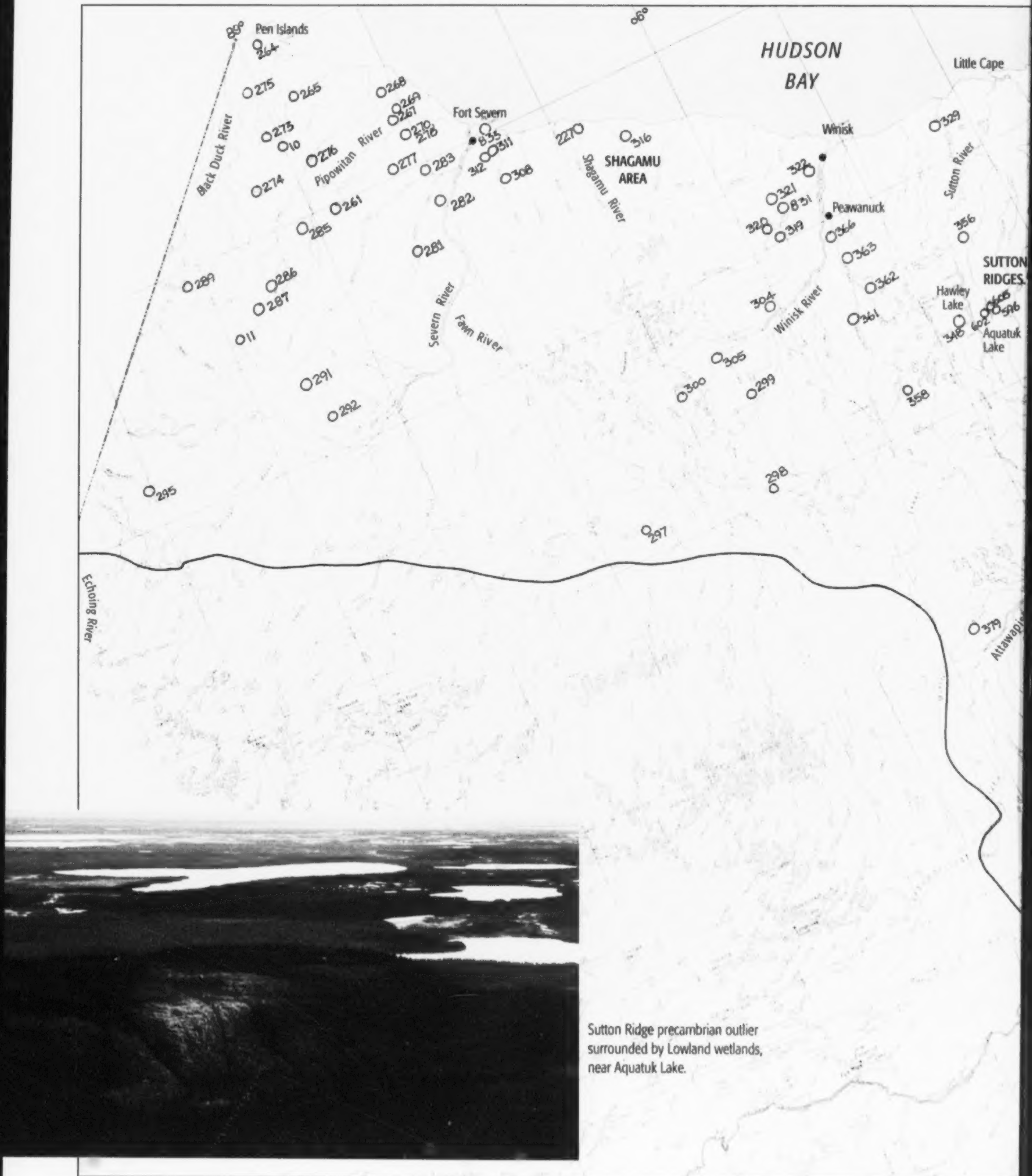
D. Attawapiskat River karst (1977, Cowell and Riley 1978), quadrat, transects;

E. Lower Shagamu River (1977), quadrats, transects;

F. Hawley and Aquatuk Lakes (1980, McAndrews *et al.* 1982), quadrats;

G. Coastal surveys within 20km of the coast (1990, Wilson 1990), quadrats; and

H. North Point and sample sites inland (August 1990), quadrats, transects, mapping (same sites sampled by North Wetlands Study, Klinger and Short 1996).



Sutton Ridge precambrian outlier surrounded by Lowland wetlands, near Aquatuk Lake.

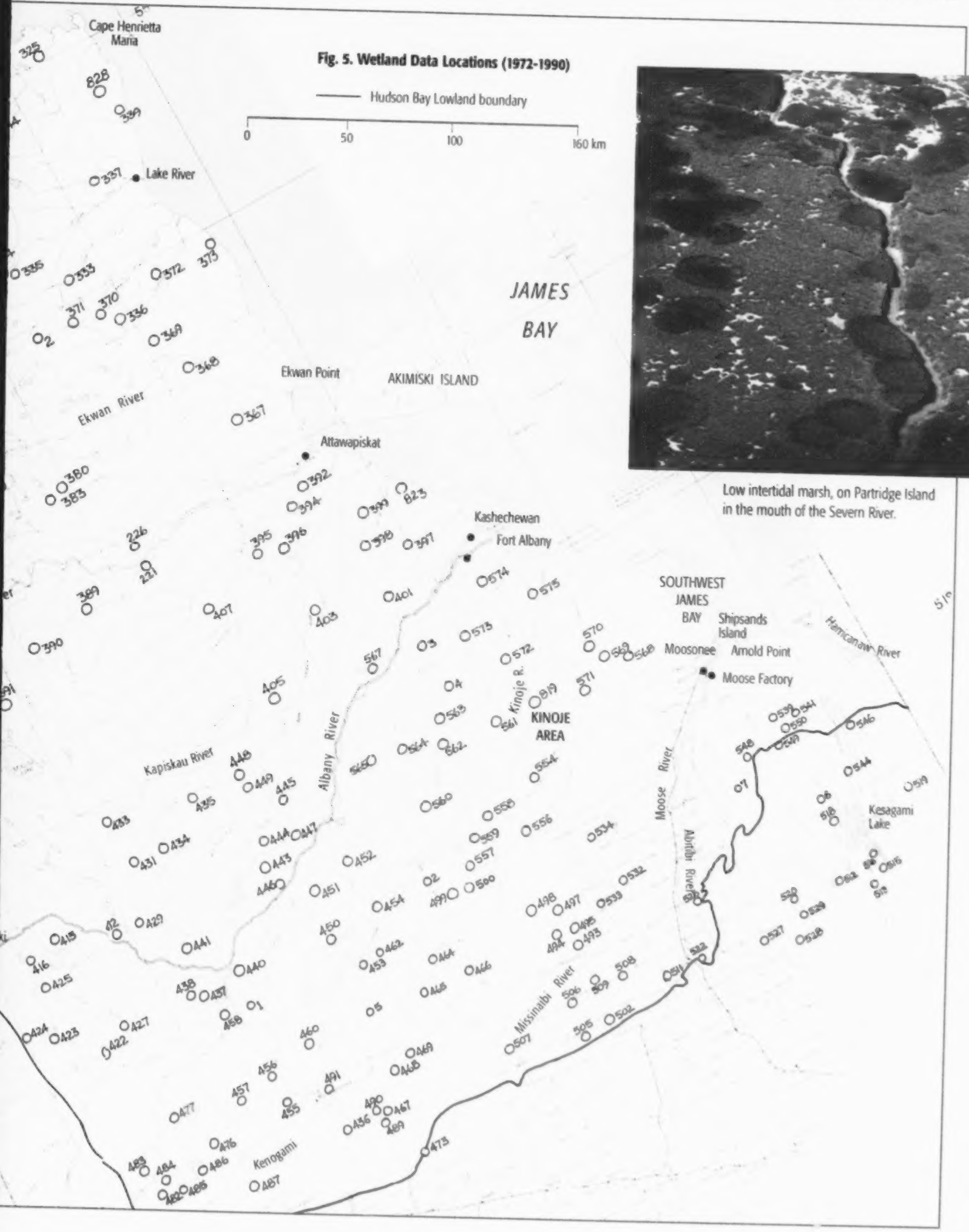


Fig. 5. Wetland Data Locations (1972-1990)

Low intertidal marsh, on Partridge Island in the mouth of the Severn River.

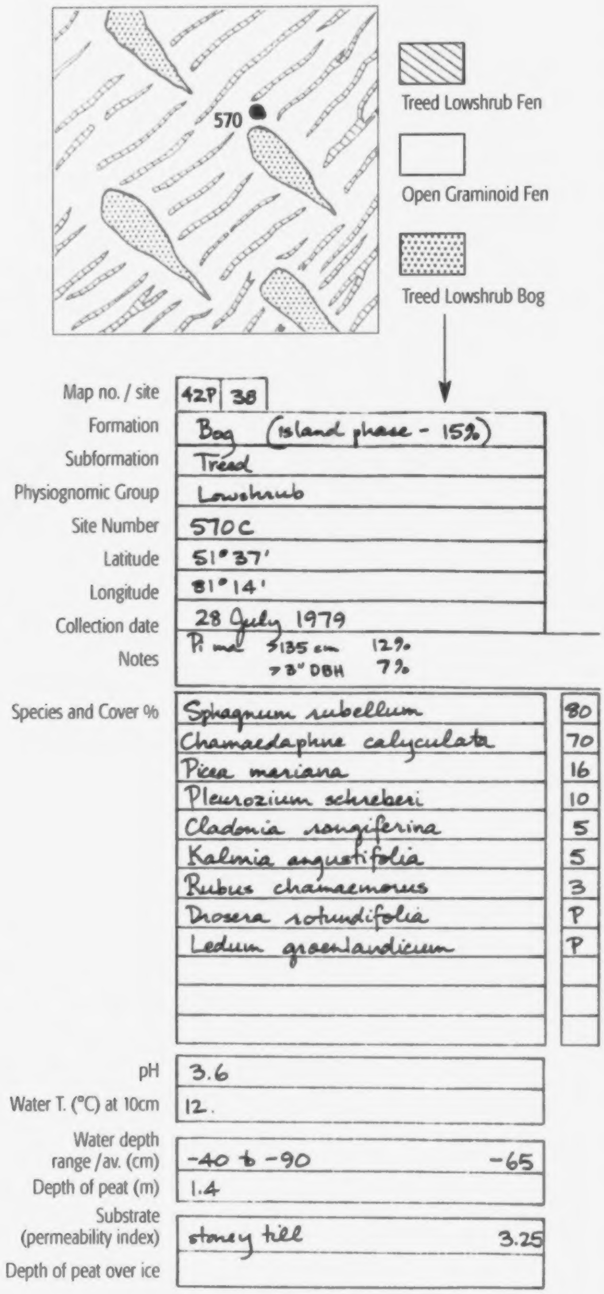


Fig. 6. Wetland data collection

Environmental Parameters

The two environmental regimes most powerful in discriminating among northern wetland types have surrogate measurements that can be sampled in the field; moisture-aeration and nutrient-pH regimes (Jeglum 1973). These were the environmental measures found to strongly discriminate among wetland types (Jeglum 1974 a,b), and which were consistently recorded in the field surveys reported here: water pH (surrogate for nutrient-pH regime) and depth-to-water (range and mean values, -ve and +ve; a surrogate for moisture-aeration regime). Also recorded in these surveys were: water temperature, depth of peat, substrate (coded to reflect permeability or average clast size; Fig. 6, 7), and the presence of continuous (impenetrable with peat rods) or discontinuous (penetrable) permafrost (and ice lenses).

Site pH was measured in the field, to the nearest 0.1 units, using E. Merck ColorpHast® 3-part pH Indicator Sticks in the ranges 0-6.0 and 5.0-10.0. Periodic checks on these pH measurements were made with portable pH meters at Moosonee, Attawapiskat and Winisk, which suggested an accuracy of approximately ±0.2 units. The pH was measured in water taken in small sample bottles 10cm below groundwater level. Where peats were not saturated, water was taken as close to the water table level as possible by cutting out a sampling pit, and squeezing out a water sample from recovered peat as close to water level as possible. Temperature was recorded for the same samples.

Depth-to-water was recorded as a positive or negative value, both as a range value and a mean value (subjectively) at each sample site.

Peat depth was recorded using extendable peat rods, and peat stratigraphy was observed using a customized stainless-steel Macaulay auger (5cm diameter by 50cm long). Recovered peats were sampled in the hand as constituent intervals based on changes in peat type and peat decomposition (botanical constituents and von Post degrees of humification; Henderson and Doiron 1982, Riley and Michaud 1994). Changes in botanical composition illustrate wetland succession over time, and field observations were made of gross peat and non-peat types: moss peat (dominated by *Sphagnum* peat or brown-moss peat); sedge peat (*Carex*, graminoids, forbs); woody peat (dominated by tree wood or shrub wood); marl; and, rarely, basal ooze (*gyttja* or *dy*).

Fig. 7. Coding of substrate permeability (by observed average basal clast size)

(Based on clast-size distribution)
6.0 (cobble-boulder, >200mm),
4.0-5.0 (gravels; 2.0-200mm),
3.0-4.0 (coarse sand, 0.2-2.0mm),
2.0-3.0 (fine sand 0.02-0.2mm),
1.0-2.0 (silt, 0.002-0.02mm),
0-1.0 clay (0-0.002mm)

5.25 coarse gravel-boulder
5.0 gravel
4.65 sandy gravel
4.35 medium sand and gravel
4.0 pebbly sand, coarse sand
3.75 sand, beach sand
3.5 rocky till

3.25 pebbly till, stoney till
3.0 coarse till, medium sand
2.75 sandy till
2.5 fine sand
2.25 very fine sand, silty sand
2.0 sandy silt, gritty sand, alluvial silt

1.7 silty till, silt
1.5 till, clay till, washed till, stoney clay
1.25 gritty clay, lacustrine clay, clay silt, silty clay
1.0 clay, marine clay, clay (marine), laminated silt

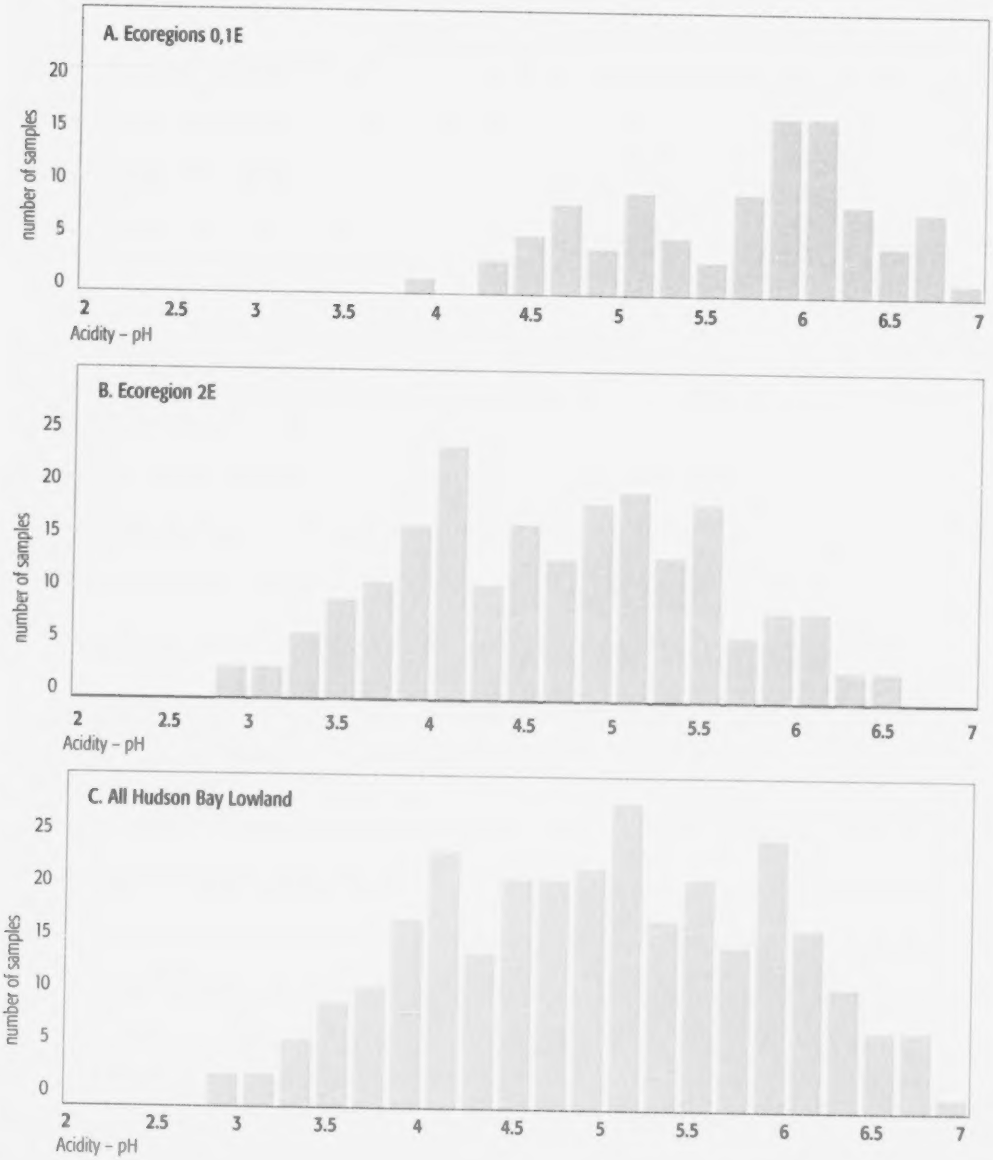
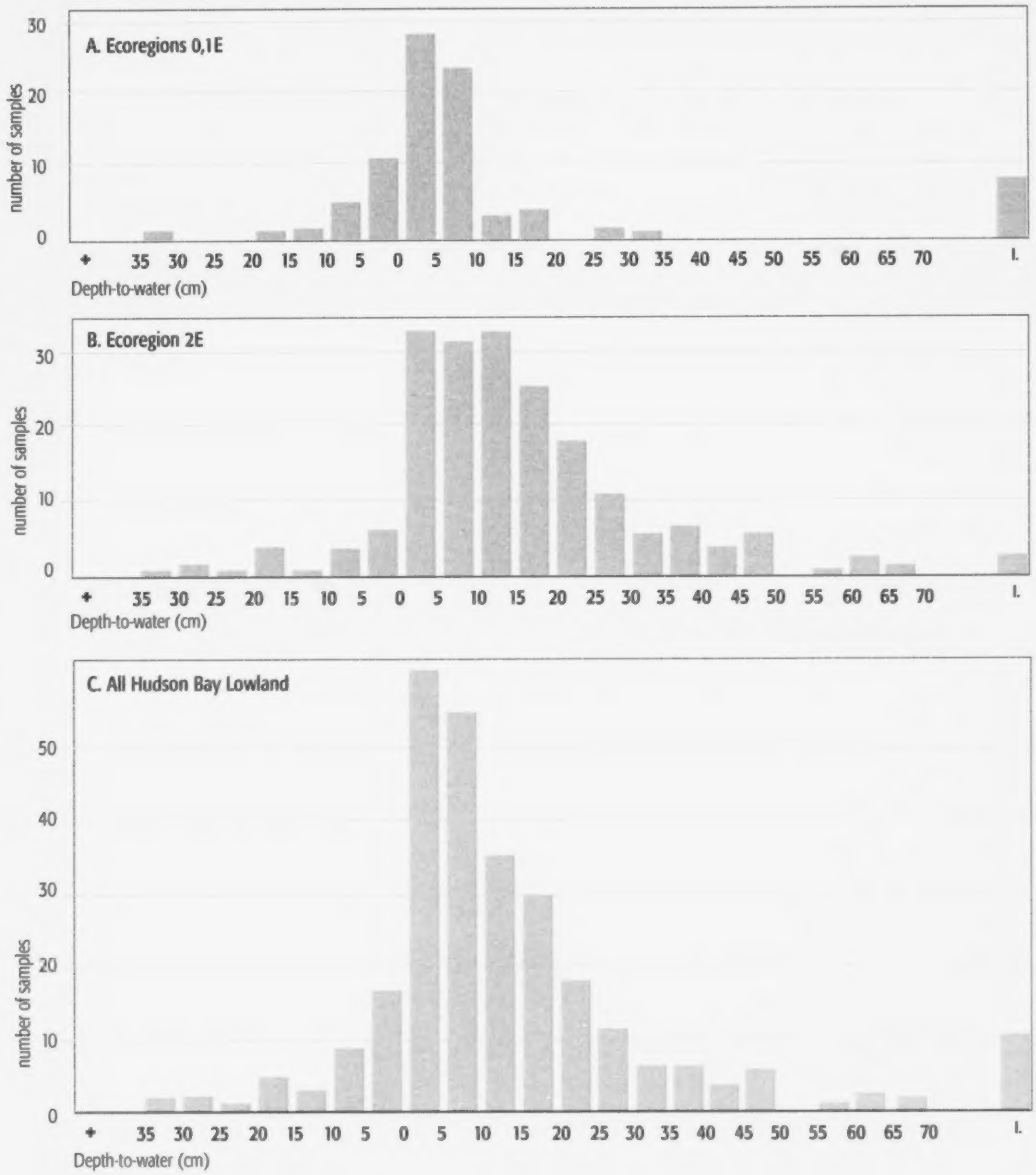


Fig. 8. Number of sample sites and surface-water pH.

Fig. 9. Number of sample sites and depth-to-water.

[1] Unsaturated, usually a permafrost-related condition.



Basal materials were extracted by auger, and substrates were characterized in the field by the author or by A. Boissonneau (Ontario Centre for Remote Sensing), assisted in some cases by A. J. Cooper or E.V. Sado (Ontario Geological Survey). Observations of substrate type were coded on the basis of average substrate clast-size/permeability (Fig. 7). (Based on the postglacial history of gradual emergence of the Lowland from the sea, two other variables were recorded for statistical analysis: 1) elevation of site above sea level; and 2) distance of the site from nearest coast.)

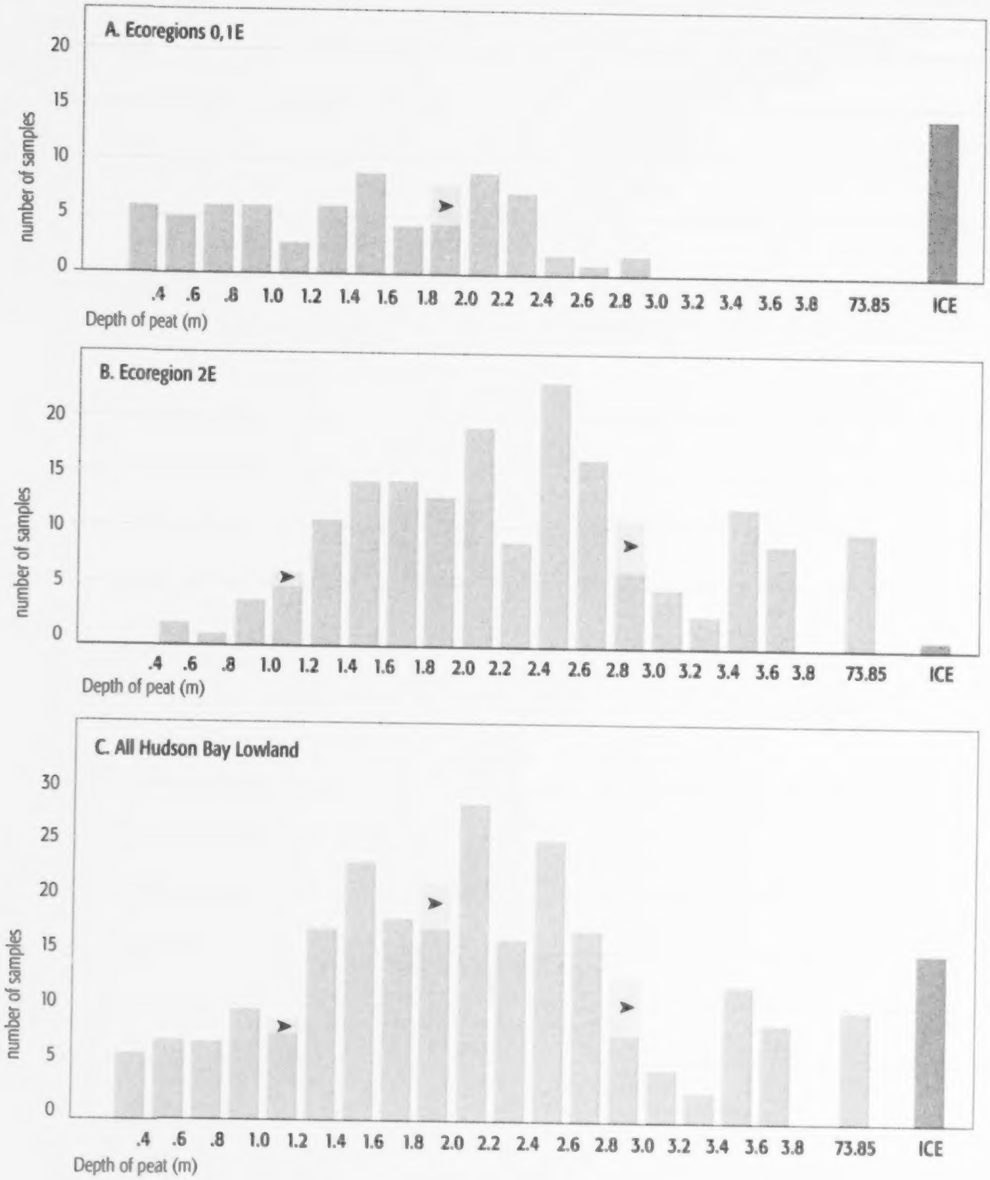


Fig. 10. Number of sample sites and peat depth.

Note: Arrows indicate sample depths greater than values plotted, based on unreached depths.

Balancing the lack of intensive, instrumented site sampling in this survey was its consistency of application and its breadth of geographic coverage among all major dominance types. Measures of the representation achieved by these methods are indicated in Figs 8-10, which graph the number of site samples per subunit of surface-water pH, depth-to-water, and depth of peat. The graphs present the totals, and the data divided by regional occurrence (ecoregions 0E, 1E and 2E). (Note the clear skew in data towards shallower peats and higher pH values in ecoregions 0E and 1E, reflecting the immense latitudinal shift in survey geography.)

Environmental Variability

Permafrost peatland complex of bog ribs and fen flats and pools, Shagamu River interior.

Summary data from all sampled wetlands are included in the catalogue of wetland site types (App. C), and in the summary of dominance types, distribution and permafrost (App. B). All of these catalogued types are referenced in the following general descriptions of the variability of Lowland wetlands, both mineral and organic. The following section, however, focuses on the quantitative vegetation ordination that was completed for a subset of 309 sampled site types in the Lowland.

This subset of sampled wetlands offers the possibility of a broad statistical and geographic overview of Ontario's subarctic wetlands. It does not offer detailed analyses of wetland succession at particular sites, but illustrates the general relationships of major wetland types. The vegetation data (species and cover values) for 309 sites were ordinated by detrended correspondence analysis according to the Cornell Ecology Program DECORANA (Hills 1979). Ordinations were plotted for 309 sample sites overall, and for subsets from ecoregion 2E (n=209) and ecoregions 0E and 1E, excluding marshes (n=91) (Fig. 11-13). Statistical correlations between strongest ordination axes and environmental parameters were calculated (Tables 2-4).

The ordinations distinctly segregate the two major wetland series; minerotrophic wetlands (marsh, fen), and ombrotrophic wetlands (bog, peat plateau). Within these two series, the ordinations segregate physiognomic and subformations less distinctly, but with clear and consistent shifts from wet to dry site types. The wetland types used in this report's keys and catalogues are superimposed on the following figures, to illustrate this general variability.

All Sites (Fig. 11, axes 1, 3): Segregates nutrient-poor types (bog, peat plateau/palsa, black spruce conifer swamp) from more nutrient-rich types (marsh, fen, tamarack conifer swamp), with some overlap of open graminoid bogs and fens. Within each of the two major nutrient-regime types, there is a secondary gradation from wetter to drier wetland types.

Ecoregion 2E (Fig. 12; sites south of ca. 53°N); axes 1, 2): Illustrates same segregation of nutrient-poor and nutrient-rich types, at around pH 5.0 (as illustrated).

Ecoregions 2E, 0E and 1E (Fig. 13, sites north of ca. 53°N; axes 1, 1): Illustrates same segregation into two nutrient groupings, strongly segregated around pH 5.2.

NUTRIENT REGIME AND MOISTURE-AERATION REGIME

Nutrient regime and moisture-aeration regime are the variables most strongly correlating with vegetational variability. For example, for all Lowland sites (Fig. 10, Table 2), axis 1 correlates most strongly with surface-water acidity (r=0.845, p<.0001, n=305). This is the case as well for sites in ecoregion 2E (Fig. 12, Table 3), and ecoregions 0E and 1E (Fig. 13, Table 4). Again, for all Lowland sites (Fig. 11), axis 3 correlates most strongly with average depth-to-water (r=0.530, p<.0001, n=309). This is also the case for sites sampled in ecoregion 2E (axis 2; Fig. 12, Table 3).

Table 2. Correlation coefficients between environmental parameters and axes of vegetation ordination; all sites.

	Surface water pH	Depth-to-water	Peat depth	Water temperature	Substrate type	Presence of ice	Elevation	Distance-to-coast	Latitude	Longitude
Axis 1	-.845(305)***	.556(300)***	.353(286)***	-.182(298)**	-.178(253)**		.259(306)***	.257(308)***	-.341(309)***	-.206(309)**
Axis 2	-	.331(300)***	-.248(286)***	-.491(298)***	-	.444(307)***	-.208(306)**	-.259(308)***	.374(309)***	.220(309)***
Axis 3	-.226(305)***	.530(300)***	-	-.229(298)***	-	-	.165(306)**	.190(308)**	-.317(309)***	-.242(309)***
Depth-to-water	-.533(296)***									
Peat depth	-.474(283)***	-								
Water temperature	-	-.227(291)***	.316(278)***							
Substrate type	.222(252)**	-	-.246(253)***	-						
Presence of ice	.145(303)*	-	-	-.284(298)***	-					
Elevation	-.339(302)***	.127(297)*	.437(283)***	.282(297)***	-	-.305(304)***				
Distance-to-coast	-.334(304)***	-	.434(285)***	.340(297)***	-.262(252)***	-.379(306)***	.635(305)***			
Latitude	.513(305)***	-.369(300)***	-.486(286)***	-.313(298)***	.214(253)***	.575(307)***	-.454(306***	-.579(308)***		
Longitude	.324(305)***	-.346(300)***	-.133(286)*	-	-	.394(307)***	-	.123(308)*		

(followed by n=number of sites; * = P<0.05, ** = P<0.005, *** = P<0.0001).

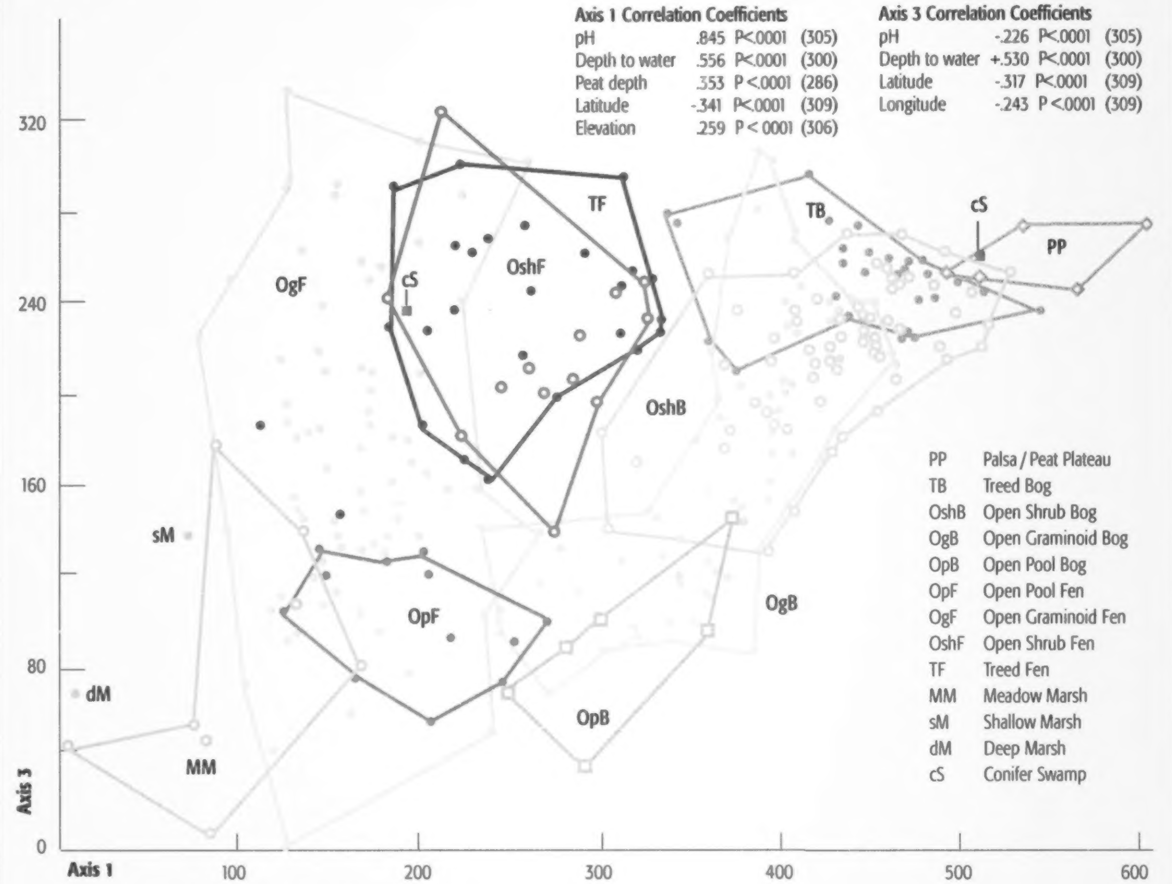


Figure 11. Hudson Bay Lowland Wetlands – All Sites (309)

These ordinations illustrate general geographic trends. For example, there is a general rise in site pHs northward (Fig. 14), with less acid bogs and fens northward (in shallower peat). Figure 15 shows this general shift of nutrient status towards more alkaline sites in ecoregions 0E and 1E (Riley 1982). North of 53°N there were no peatlands sampled with surface-water pH less than 4.0. There is also a regional shift northward towards raised permafrost peat plateaus, and these represent the extremes of site acidity in ecoregions 0E and 1E (Fig. 13). In ecoregion 2E, extremely rich marl fens and shallow coastal fens often have pHs exceeding 6.5 but these are rare types not included in the analyzed sample set. On the other hand, water pHs in peatlands of ecoregions 0E and 1E regularly exceed 6.5. In general, bogs (pH less than 5.1) are the dominant peatland types in ecoregion 2E, while fens (pH >4.9) and bog-like PEAT PLATEAUS dominate ecoregions 0E and 1E.

PEAT DEPTH

Peat depth varies most directly with surface-water pH, as is clear in the ordinations. Bogs are more acid and have deeper peats, averaging >2.55m deep in the south (ecoregion 2E; ±0.79, n=124) and >1.82m deep in the north (ecoregions 0E,1E; ±0.56, n=33). On the other hand, fens are less acid and have shallower peats over mineral substrates, averaging 2.15m deep in the south (ecoregion 2E; ±1.11, n=76) and 1.37m deep in the north (ecoregions 0E,1E; ±0.73, n=31). For all sample sites, peat depth increases with decreasing pH ($r=-.474$, $p<.0001$, $n=283$). The same holds for both southern and northern subsamples, and peat depth also increases with elevation (longer periods of peat accumulation) and decreases with latitude (slower rates of peat accumulation).

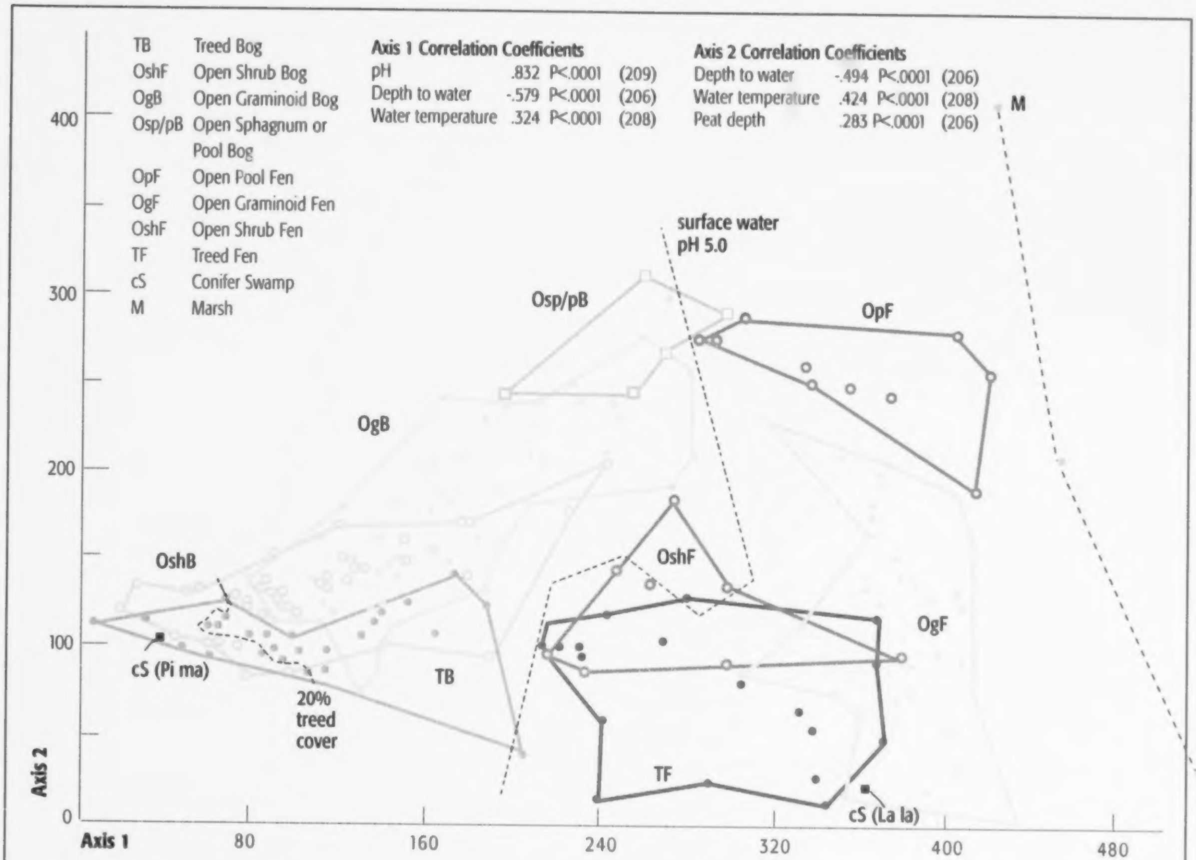


Figure 12. Hudson Bay Lowland Wetlands – Sites South of 53°N (209 sites) (excluding Meadow Marsh)

Table 3. Correlation coefficients of environmental parameters and axes of vegetation ordination; sites south of 53°N Lat (+/- ecoregion 2E)

	Surface water pH	Depth-to-water	Peat depth	Water temperature	Substrate type	Presence of ice	Elevation	Distance-to-coast	Latitude	Longitude
Axis 1	.832(209)***	-.579(206)***	-.194(206)*	.324(208)***	.176(188)*	-.180(209)*	-.197(209)**	-.163(209)*	.246(209)**	-
Axis 2	-	-.494(206)***	.283(206)***	.424(208)***	-	-	-	-	-	-
Axis 3	-	-	-	-	-	-	-	.138(209)*	-	.244(209)**
Depth-to-water	-.497(206)***									
Peat depth	-.351(206)***	-								
Water temperature	.202(208)**	-.384(205)***	.262(205)***							
Substrate type	-	-	-	-						
Presence of ice	-.155(209)*	.158(206)*	-	-.177(208)*	-					
Elevation	-.255(209)**	-	.371(206)***	.179(208)*	-	-.186(209)*				
Distance-to-coast	-.154(209)*	-	.307(206)***	.205(208)**	-.268(188)**	-.201(209)**	.548(209)***			
Latitude	.304(209)***	-.202(206)**	-.502(206)***	-.309(208)***	-	.146(209)*	-.461(209)***	-.420(209)***		
Longitude	-	-.251(206)***	-	-	-.212(188)**	-	.212(209)**	.765(209)***		

(followed by n=number of sites; * = P<0.05, ** = P<0.005, *** = P<0.0001).

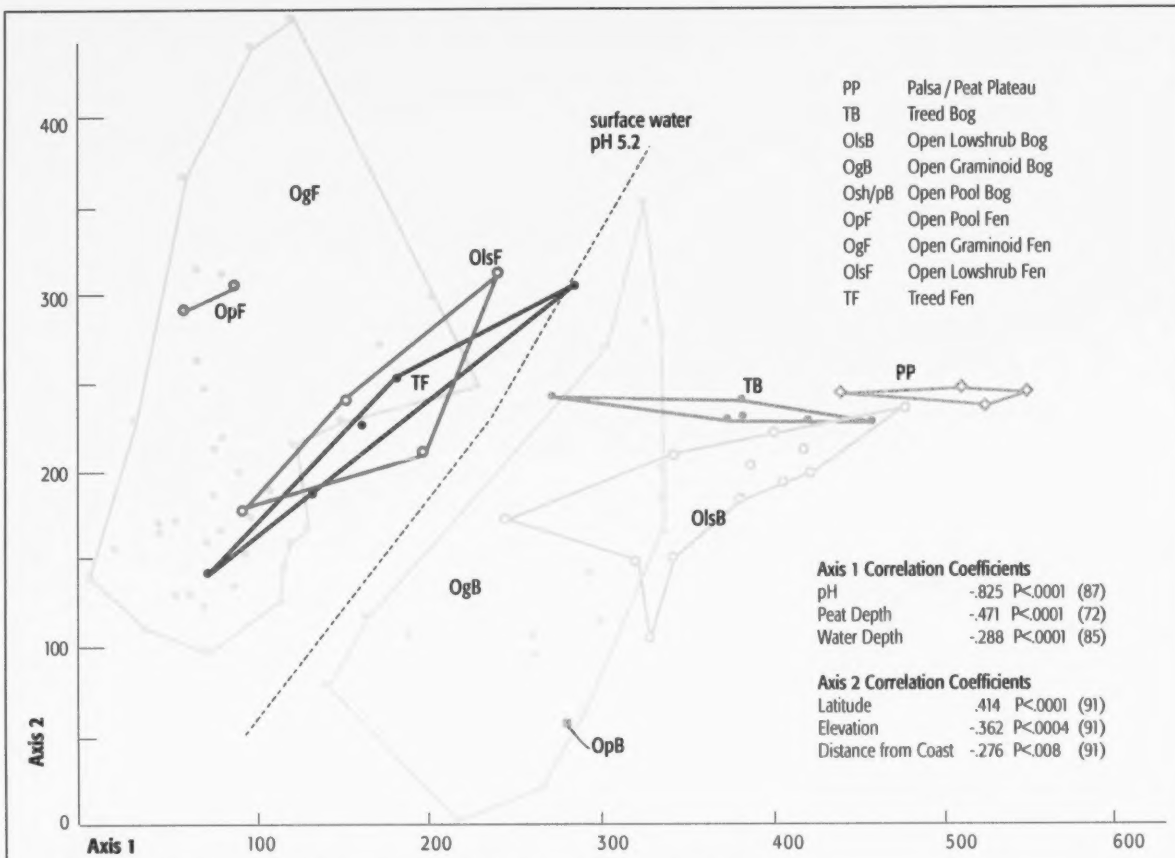


Figure 13. Hudson Bay Lowland Wetlands – North of 53°N (91 sites) (excluding Meadow Marsh)

Table 4. Correlation coefficients of environmental parameters and axes of vegetation ordination; sites north of 53°N Lat (+/- ecoregions 0,1)

	Surface water pH	Depth-to-water	Peat depth	Water temperature	Substrate type	Presence of ice	Elevation	Distance-to-coast	Latitude	Longitude
Axis 1	-.825(87)***	.288(85)*	.471(83)***	-.263(83)*	-	.258(89)*	-	-	-	-
Axis 2	-	-	-	-	-	-	-.362(91)**	-.276(91)*	.414(91)***	.235(91)*
Axis 3	-	-	-	-	-	-	-	-.232 (91)*	-	-.221(91)*
Depth-to-water	-.216(81)*									
Peat depth	-.368(69)**	-								
Water temperature	-	-.256(79)*	-							
Substrate type	-	-	.347(59)**	-						
Presence of ice	-	-	.314(72)**	.230(83)*	-					
Elevation	-	-	.386(72)**	.355(83)**	-	-.252(89)*				
Distance-to-coast	-	-	.341(72)**	.499(83)***	-	-.284(89)*	.781(91)***			
Latitude	.235(87)**	-.312(85)**	-	-	-	.446(89)***	.322(91)**	-.355(91)**		
Longitude	-	-.259(85)*	.365(72)**	.349(83)**	-	.243(89)*	-	.274(91)*		

(followed by n=number of sites; * = P<0.05, ** = P<0.005, *** = P<0.0001).

The data suggest a nearly exclusionary relationship of pH to peat depth, in that pHs from less than 2.9 to 4.0 do not occur in peatlands with peat depths less than 1.5 m (see lower diagonal line on Fig. 15). It should also be noted that peat depths in excess of 3.9m were not uncommon in ecoregion 2E but could not be sampled; this is especially the case south of 51°N latitude. The relationship between wetland type and peat depth will be important in calculating peat (carbon) volumes for the Lowland, and the relationship between the two deserves close attention before 'average peat depths' are assigned to remotely mapped wetland types.

The relationship of pH to peat depth in ecoregions 0E and 1E shows generally elevated pHs northward, apparent even in peatland sites with permafrost. This may be partially attributable to undersampling of peat plateaus, or the result of sample water squeezed from dry peat in raised sites, or from higher oxidation in drier active layers. However, it remains a consistent shift to less acidic sites northward, and there are no anomalous outliers in the sampled data (Fig. 14).

GEOGRAPHIC VARIATION

There are strong correlations between peat depth, distance from the coast and elevation (Fig. 10), both of which also strongly and positively co-vary ($r=.635$, $p>0.0001$, $n=305$). This reflects the ongoing uplift of the Lowland from the sea over the past 5500 years, leaving behind flat marine clays suited to water retention and peat accumulation (Riley 2003, Fig. 18). The northward shift towards fen reflects the cooler climate of ecoregions 0E and 1E (restraining peat growth) and the shorter period of emergence from the Tyrrell Sea of most northern sample sites (less time for peat accumulation). In general, the greater the distance from the coast, the higher the elevation of the site, the longer the period of emergence and the deeper the peat accumulated as a result (other variables being equal).

As well, the prevalence of *Sphagnum* in bogs, because of its superior insulating properties, shifts northern bogs to palsa and peat plateau. The analysis of all sample sites illustrates this positive correlation of the presence of ice in the peat with higher latitude (Table 2, $r=.575$, $P>0.0001$, $n=307$), and also with elevation and with closeness-to-coast. (The impenetrability of ice in peat plateaus reduced the data on their peat depths below levels useful for analysis; it can be assumed that their frozen peats average >3m in depth based on the sites drilled to date by Zoltai and Tarnocai 1971, Railton and Sparling 1973, OCRS, etc.)

Surface-water pH increases with latitude, paralleling the shallower peat depths northward (Table 2, $r=.513$, $P>0.0001$, $n=305$). This reflects the nutrient contribution of mineral substrates in shallower peatlands, with less-acid surface waters as a result. The strong inverse correlation of surface-water pH and depth-to-water illustrates that, where peatlands are driest (i.e., bogs, with deepest average peat depths) the surface waters are most nutrient poor.

These general co-variances of wetland characteristics are explicable by both geography and succession. The data fail to show comparable patterns in depth-to-water characteristics, water temperatures or substrate characteristics, variables which are probably more locally determinant, in the case of the first two, or a common attribute of all sites, as in the latter case, with marine clay and silt substrates underlaying wetlands throughout the Lowland.

The correlations based on **sites in ecoregion 2E** only (generally south of the Attawapiskat River) (Fig. 12, Table 3) corroborate the regional relationships. However, the geographic effects of site latitude are more muted (on surface-water pH and presence of ice), while there is an even stronger correlation of site latitude with decreasing peat depth (depth declines northward, $r=-.502$, $p>0.0001$, $n=206$). This reflects the less dramatic climatic effects of Hudson Bay so far south, the general occurrence of only discontinuous permafrost, and the effect of cooling climate on slowing peat accumulation.

Because of the north-south axis of the western James Bay coast, it might be expected that strong positive correlations should occur between site longitude (and distance-from-coast) and peat depth, reflecting increased landscape age towards the interior. These correlations are not strong, perhaps reflecting the particular topographic diversity of the southern Lowland, which is muted but powerful. There is a major topographic upland, the Kinoje till plateau, separating the Albany and Moose watersheds (Pala and Wischet 1982), and this somewhat mutes the relationship between site elevation and distance-to-coast. Except in near coastal sites, where peat depths are maximally constrained by the short duration of site emergence from the sea, peat depths vary considerably, dependent on local hydrology and topography, etc.

LEFT. Open lowshrub bog, on Moose-Albany watershed, Kinoje till plateau. RIGHT. Ice at 30cm, Moose-Albany watershed, Kinoje till plateau.

For sites in ecoregions 0E and 1E (generally north of the Attawapiskat River), there are stronger geographic patterns of environmental parameters because of the steeper and more uniform slope of the terrain northward, downhill, close to Hudson Bay (Fig. 12, Table 4); distance-from-coast and site elevation are dependent variables ($r=.781$, $P>0.0001$, $n=91$). The surface-water temperatures in the peatlands decline and the frequency of ice in the peat increases with proximity to the coast, and with north latitude.

Peat depths in ecoregions 0E and 1E are also positively associated with the presence of ice in the peat, in this case in the sampled palsas and peat plateaus, but also likely in other permafrost types. Peat depth also increases with site elevation and distance-from-coast, in this case generally towards the south and west of ecoregions 0E and 1E.

PERMAFROST

In general, the presence of ice, whether continuous or discontinuous, correlates most positively with latitude (Table 2) but also inversely with distance-to-coast and elevation, which are two strongly linked variables. These predictable results are based on relatively sparse sampling of the presence of ice, but the distribution of sites suggests a more widespread occurrence of discontinuous permafrost than previously considered, both towards the southwest interior as penetrable ice lenses (discontinuous ice) and southward along the James Bay coast as sporadic but impenetrable ice assumed to be >30cm thick (i.e., not penetrable by steel peat rods).

Surface-water temperatures were collected without expectation of overall trends but significant correlations emerged nonetheless. There is a positive correlation of temperature with peat depth and a negative correlation of temperature with depth-to-water, confirming field observations that cold is retained longest in drier, deeper peat types (*i.e.*, bogs). There are also positive correlations with distance-to-coast and elevation (+ve), and a general shift to cooler water temperatures northward and closer to the coast, and with presence of ice at sites. Temperature is not usually considered a useful discriminator in field surveys, even where mid-summer temperatures are measured in consecutive years, as was the case here, but long-term monitoring of northern wetlands, especially permafrost systems, warrants closer study of peat temperatures, and a standardization of methods to survey water and peat temperatures.

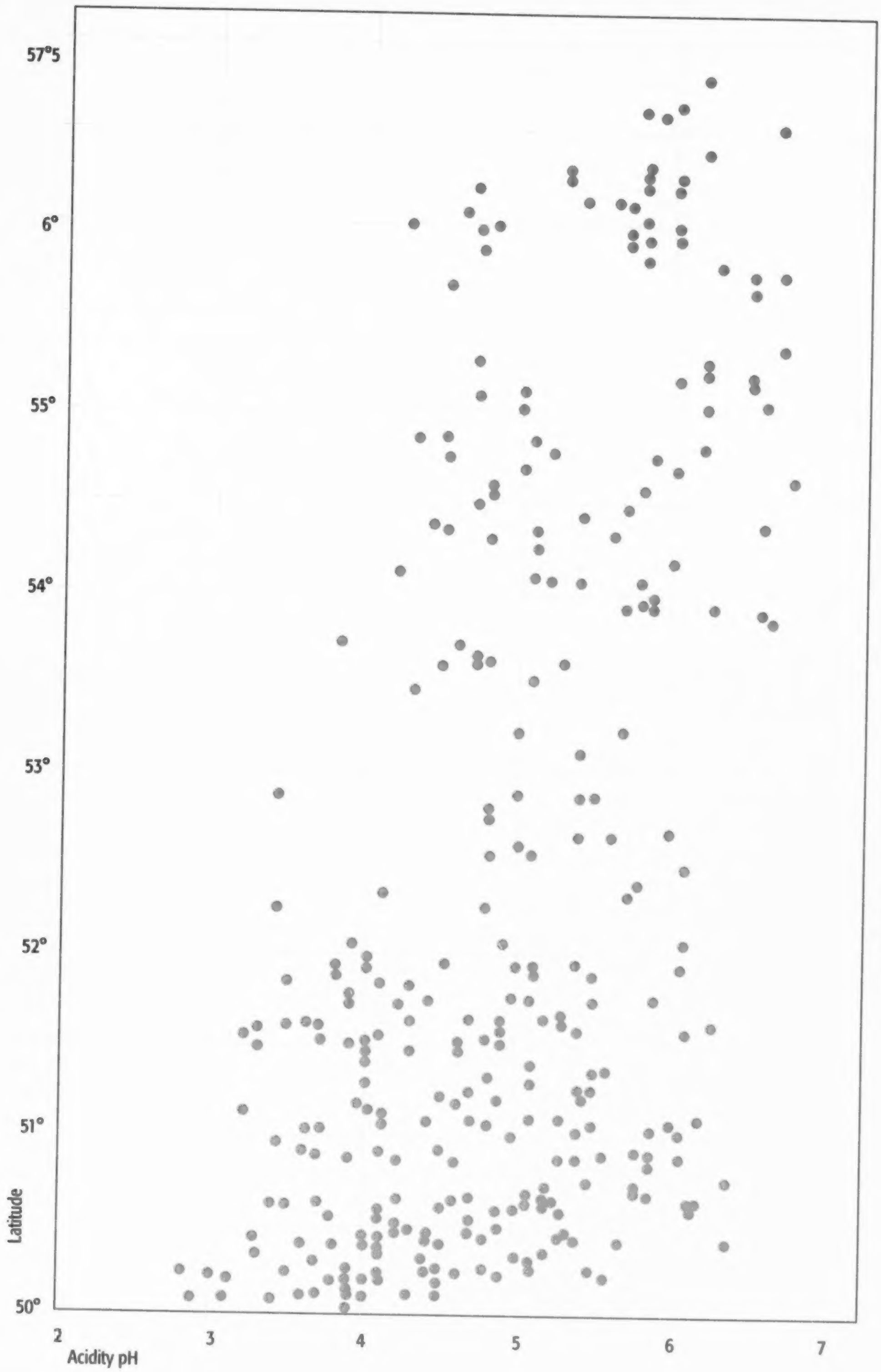


Fig. 14.
Site latitude and surface-water pH.

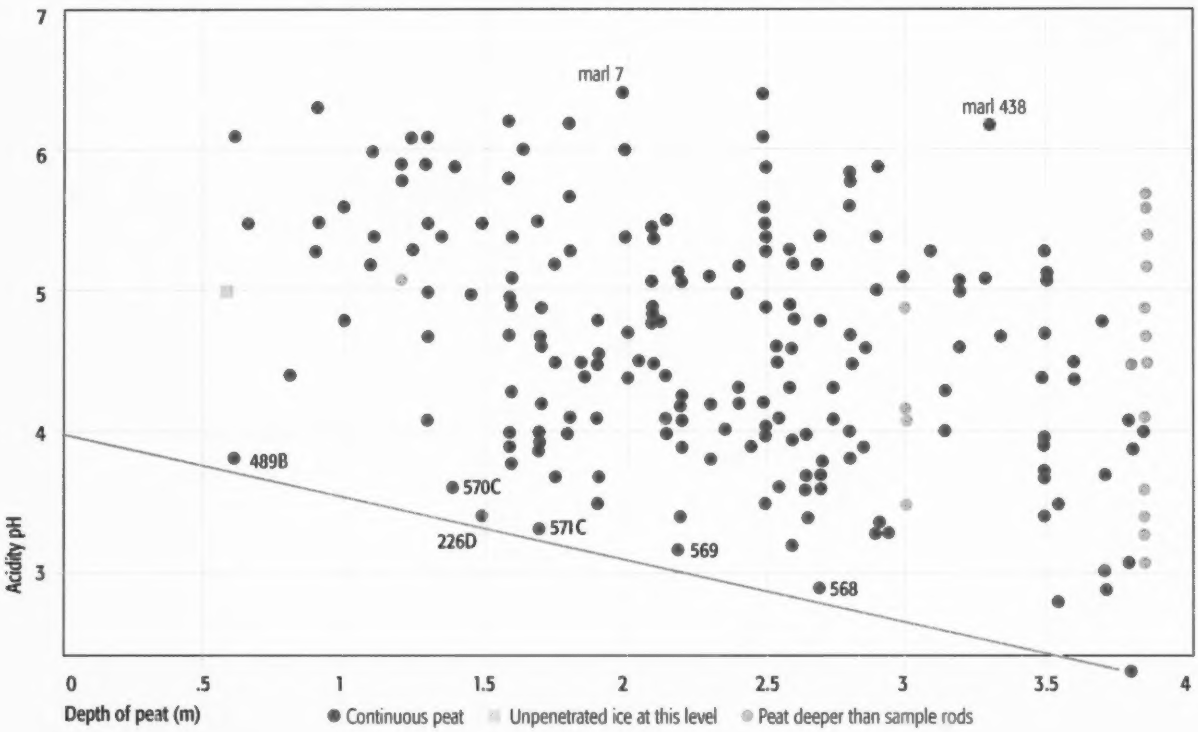


Fig. 15. Surface-water pH and peat depth in ecoregion 2E. (Outlier site numbers added, Fig. 5)

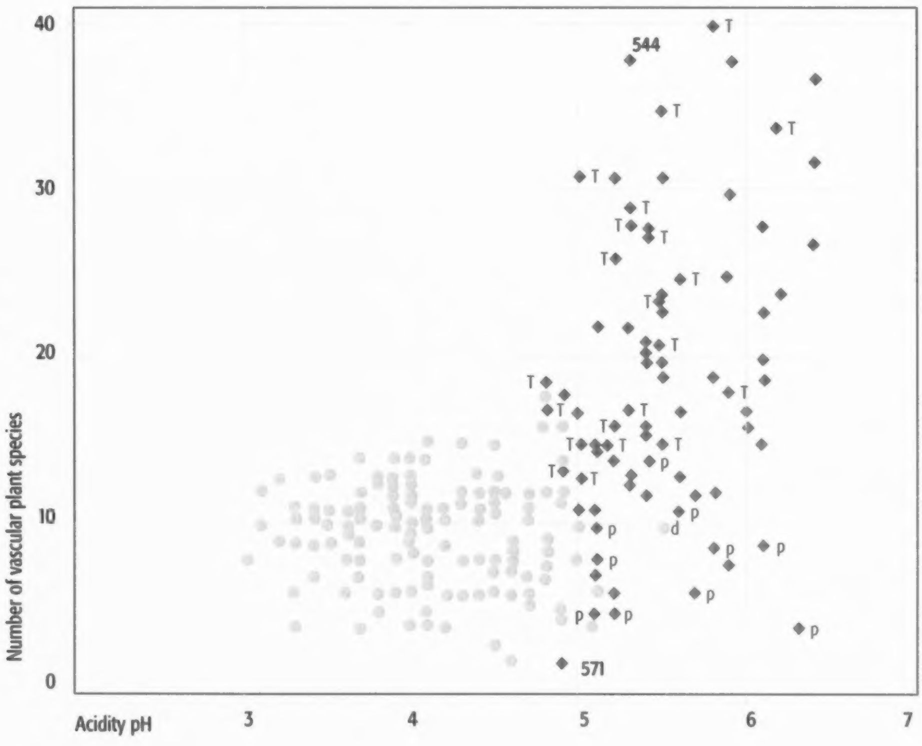


Fig. 16. Number of vascular plant species and surface-water pH in wetlands in ecoregion 2E.

Bogs
Fens
Fen pool p
Treed fen T
Dry bog d

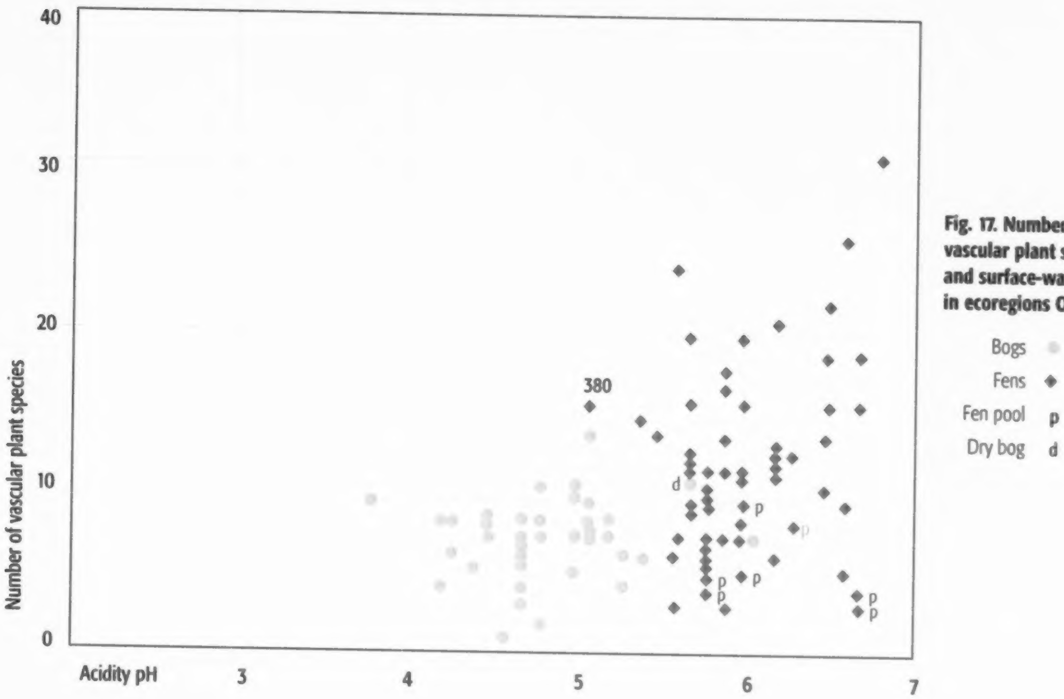


Fig. 17. Number of vascular plant species and surface-water pH in ecoregions 0, 1E.

SPECIES DIVERSITY

The predictability of lower floristic and insect diversity in acid bogs, in comparison with fens, is well documented (*e.g.*, Riley 1994b) but is particularly dramatic in the Hudson Bay Lowland, in which species diversity is already reduced by latitude. The number of vascular plants per sample site in ecoregion 2E (Fig. 16) and in ecoregions 0E and 1E (Fig. 17) are plotted against surface-water pH. This shows the dramatic increase in species numbers at sites with pH greater than 4.9 (range of 4 to 40 species) and the contracted range of species at sites with pH less than 4.8 (2 to 15). Also illustrated is the decrease in potential species at northern sites (Fig. 17), reflecting the northward decline in species diversity at higher latitudes (Riley 2003).

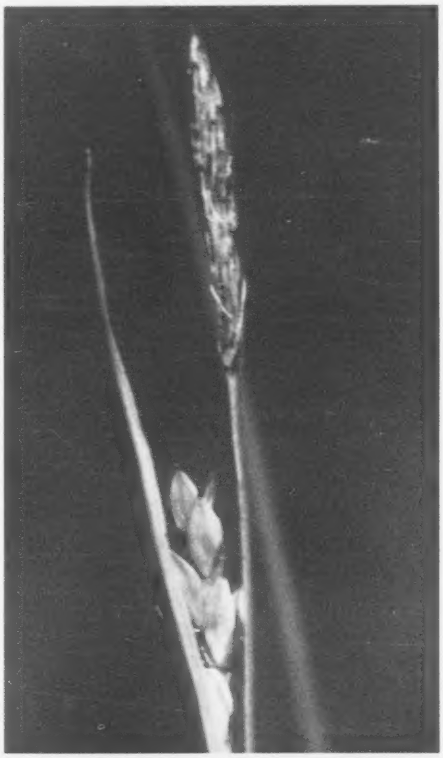
AFFINITIES OF COMMON WETLAND PLANT SPECIES

Common wetland species are indicated in the dominance types and site types catalogued in this overview (App. B, C) and are noted in particular for mineral wetlands in the keys to wetland types (App. A). The common wetland species of mineral wetlands (marsh, meadow marsh, water) do not vary with the predictability or usefulness of many peatland species, whose presence (or presence at a particular cover value) can be considered as diagnostic of a peatland type (Table 5). Many species have been graphed (surface-water pH vs. cover percent; such as for *Carex limosa*; Riley 1982, Fig. 5), and those that commonly achieve cover values >10% are included as App. D to illustrate their particular pH signatures. There is considerable fidelity in the occurrence of species within distinct pH ranges, and that many of them reach highest cover values at presumably 'optimal' pH's.

The predictability of such species occurrences is useful to field workers in rapidly characterizing particular sites as to physiognomic group or dominance type. They are valuable in judging a site to be either bog or fen, and for further judging the nutrient status, or 'richness,' of a fen (Table 5).

Particularly interesting is the apparent shift in pH preferences of species northward in ecoregions 0E and 1E. For example, *Larix laricina* was recorded at various cover values in ecoregions 0E and 1E within a pH range of 4.6 to 6.6, whereas in ecoregion 2E it was recorded within the pH range of 2.8 to 6.4. Thus it is a weak FEN indicator to the north but a more generalist species southward in the lowland. However, at cover values greater than 7%, it is a strong fen indicator in all three ecoregions.

Table 5. Common indicator species of peatland formations***



ECOREGION 2E

Strong Bog Indicators (pH<5.2)**

Carex oligosperma (rarely to pH 5.3)
Carex pauciflora (pH<4.8)
Cladina spp. (rarely present at higher pHs)
Cladopodiella fluitans
Eriorphorum spissum
Kalmia angustifolia (rarely to pH 5.3)**
Carex rariflora (rare in 2E)
*Rubus chamaemorus***
Vaccinium myrtilloides (pH<4.2)**

Weak Bog Indicators (pH<5.5)

Carex magellanica
Empetrum nigrum (rare species)
Kalmia polifolia (rarely to pH>6.0)
Sphagnum fuscum (rarely to pH6.0 at <15% cover)**

Strong Fen Indicators (pH>4.8)*

*Aulocomnium palustre**
*Campylium stellatum**
Carex diandra (pH>5.0)*
Carex exilis
Carex interior (pH>5.0)*
Carex lasiocarpa
Carex livida
Drepanocladus revolvens (pH>5.6)
Drepanocladus fluitans
Eriophorum viridicarinatum
Potentilla fruticosa (pH>5.3)
Rubus acaulis (pH>5.6)
Salix pedicellaris
Scirpus hudsonianus (rarely to pH 4.7)
Scorpidium scorpioides (pH>5.0)*
Solidago uliginosa (pH>5.0)
Triglochin maritima (pH>5.0)*
Utricularia cornuta (pH>5.0)
Utricularia intermedia (rarely to pH 4.5)*
Utricularia minor (pH>5.0)

Weak Fen Indicators (pH>4.5)

Betula pumila (pH>4.7 at >10% cover)*
Carex aquatilis (rarely to pH 4.4)*
*Carex utriculata**
*Equisetum fluviatile**
Menyanthes trifoliata (pH>4.8 * at >10% cover)
Tomenthypnum nitens (rarely to pH 4.0 at <5% cover)*

Generalists

Carex limosa
Drepanocladus exannulatus
Sarracenia purpurea
Scheuchzeria palustris
Smilacina trifolia

Indicators at Higher Covers

Andromeda glaucophylla (pH>5.0 at >15% cover)
Carex chordorrhiza (pH>5.0 at >10% cover)
Chamaedaphne calyculata (pH<5.0 at >20% cover)
Larix laricina (pH>4.8 at >10% cover)
Ledum groenlandicum (pH<5.5 at >7% cover)
Picea mariana (pH<5.5 at >10% cover)

* Asterisked species are also predictable species of freshwater marsh.

** Double-asterisked species are also predictable species of conifer swamp.

*** Species names follow Riley (2003); synonyms are noted in Appendix E.

TOP LEFT. *Carex livida*

LEFT. *Andromeda glaucophylla*

RIGHT TOP. *Solidago uliginosa*

RIGHT CENTER. *Carex oligosperma*

RIGHT BOTTOM. *Rubus chamaemorus*

ECOREGIONS 0E and 1E

Strong Bog Indicators (pH<5.2)**
Carex oligosperma (rare)
*Rubus chamaemorus***
Vaccinium myrtilloides (pH<4.6)**

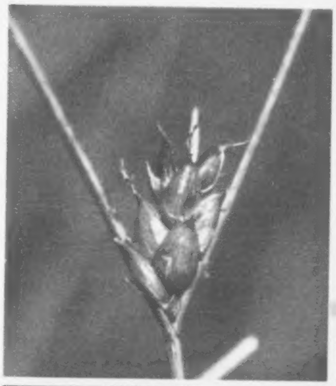
Weak Bog Indicators (pH<5.5)
Carex magellanica
Cladopodiella fluitans
Eriophorum spissum (rarely to pH 5.7)
*Picea mariana***
Sphagnum fuscum (rarely to pH 5.8)**

Strong Fen Indicators (pH>4.8)*
*Aulocomnium palustre**
Campylium stellatum (pH>5.0)
Carex chordorrhiza
Carex diandra (pH>5.6)*
Carex interior (pH>5.6)*
Carex livida (pH>5.6)
Carex microglochin (pH>5.0)
Carex utriculata (pH>5.6)*
Drepanocladus exannulatus
Drepanocladus revolvens (pH>5.5)
Drosera anglica
Equiseum fluviatile (pH>5.0)*
Eriophorum viridicarinatum (pH>5.6)
Menyanthes trifoliata (pH>5.0)*
Potentilla fruticosa (pH>5.5)
Rubus acaulis (pH>5.0)
Salix pedicellaris (pH>5.3)
Scirpus hudsonianus
Scorpidium scorpioides
(rarely less than pH>5.0)*
Solidago uliginosa (pH>5.4)
Tomenthypnum nitens (pH>5.4)*
Utricularia cornuta (pH>5.5)
Utricularia intermedia (pH>5.3)*
Utricularia minor (pH>5.8)*

Weak Fen Indicators (pH>4.5)
Andromeda glaucophylla (rare)
Andromeda polifolia (rarely to pH 4.2)
*Betula pumila**
*Carex aquatilis**
Larix laricina
Scirpus cespitosus (rarely to pH 4.4)

Generalists
Carex rariflora
Empetrum nigrum
Ledum groenlandicum
Sarracenia purpurea
Smilacina trifolia
Scheuchzeria palustris

Indicators at Higher Covers
Carex limosa (pH>5.0 at >25% cover)
Chamaedaphne calyculata (pH<5.0 at >20% cover)
Cladina spp. (pH<5.0 at >10% cover)



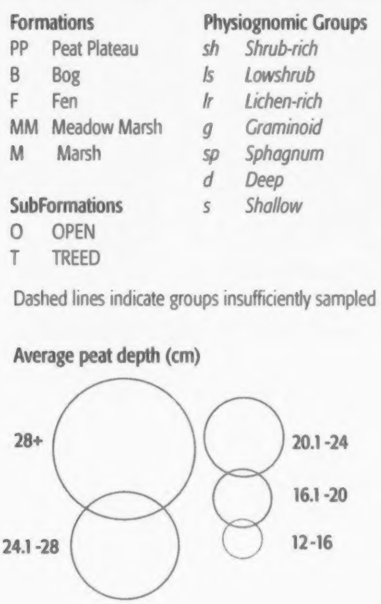
Wetland Succession

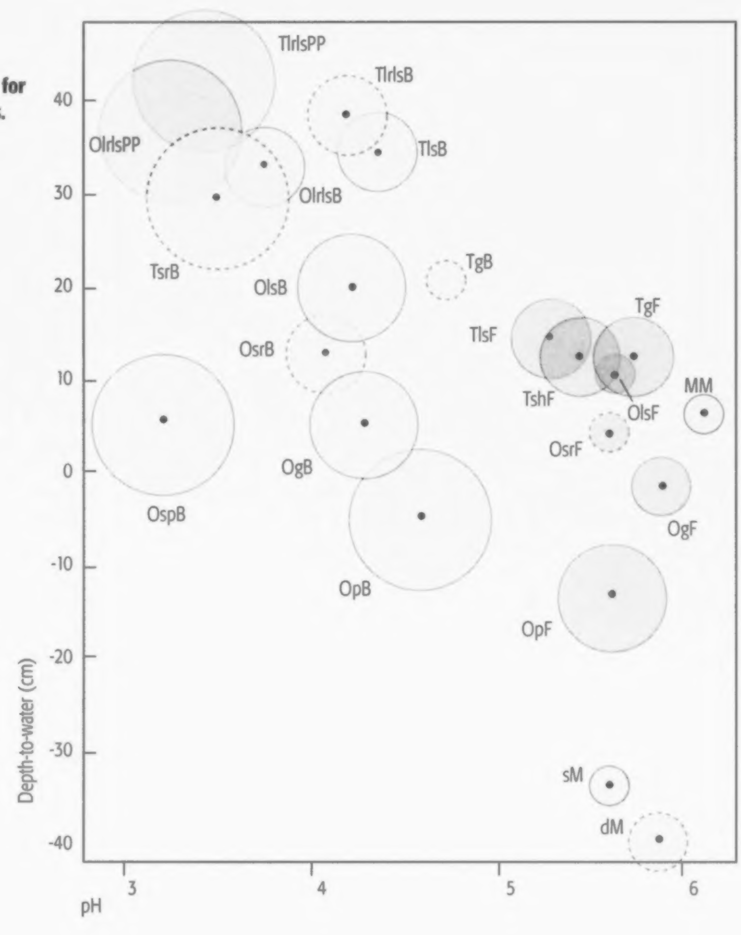
In the previous section, the variability of wetlands was discussed at broad geographic scales; in particular, the controlling influences of increasing distance-from-coast and site elevation, and of increased peat depth and lower surface-water pHs and nutrient availability. In this section, wetland variability is discussed at the scale of particular wetland types, as they succeed from one to another along those general gradients, and as they change over time, and as they occur in various patterns of differing wetland types.

The wetlands of the Hudson Bay Lowland are uniquely complex, diverse and patterned systems in which substrate deposition and vegetation development over time are driven by both external and internal processes. The region's location on the core landscape of the ancient Laurentide ice sheet, subsequently inundated by one of the globe's southernmost winter-frozen seas, resulted in unusually uniform clay-dominated (impermeable) substrates across the entire region. These factors, modified by the subsequent uplift of the land above sea level and changes in climate over the past 6000 years, were the primary external drivers shaping the region.

These externalities set the stage for a range of internal processes: vegetative growth; peat accumulation and water retention; paludification at local and landscape scales; in-filling of depressions; acidification by *Sphagnum*; pattern formation; permafrost accretion and decay; drainage shifts; and, locally, thermokarst and limestone karst. Dominant within these processes is a trajectory of change, through paludification and acidification, that is apparent throughout the Lowland, as marsh-to-fen-to-bog (-to-permafrost). This temporal succession is analogous to the lateral succession, through peat accumulation, that occurs as land emerges from the ocean. Close to the emergent coasts are marsh and shallow fen, where the unpaludified and complex interrelations of beachridges and tidelines, intervening swales and drainways, and panne-and-sward mosaics, provide insight into similar patterns among complex interior peatlands, which also reflect subtle topographic change and, northward, seasonal and continuous permafrost.

Fig. 18. Average surface pH and depth-to-water for major peatland types, with average peat depths.





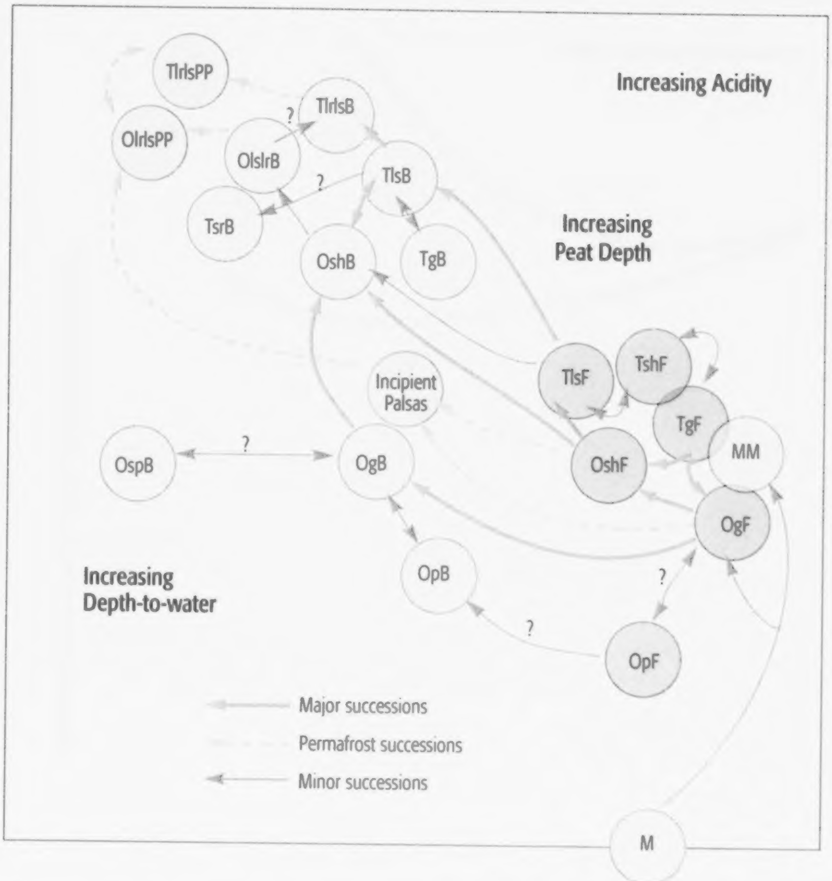


Fig. 19. Successional trends among major peatland types.

Formations
PP Peat Plateau
B Bog
F Fen
MM Meadow Marsh
M Marsh

SubFormations
O OPEN
T TREED

Physiognomic Groups
sh *Shrub*
ls *Lowshrub*
lr *Lichen-rich*
g *Graminoid*
sp *Sphagnum*
p *Pool*

Experience suggests a set of interpretative themes that may assist a field worker in understanding a particular wetland in the context of regional and temporal succession. Considering these interdependent variables at site-specific scales can help interpret local wetland variability.

- Vegetation Patterns
- Waterflow, Hydrology and Topography
- Peat Stratigraphy
- Permafrost
- Location Sequences

The interrelatedness of these factors cannot be overstated. This can be visualized by a graphic representation of the wetland types and their major environmental variables. Figure 18 portrays the general relationship of wetland type with peat depth, depth-to-water and surface-water pH, and illustrates the distinctions — over and above vegetation — that distinguish the types. This representation corroborates field interpretations of wetland succession, both major and minor, based on floristic affinities, residual indicator species, and wetland patterns. These perceived successions are reinforced by the geographic trends in increased peat depth, increased depth-to-water and decreased surface-water pH, as superimposed on the same graph of wetland types in figure 19 (Riley 1982, 1994a,b; Jeglum and Cowell 1982). This illustrates the successional pathways for low wet sites (the mesosere), which dominate as much as 90% of the Lowland. Not included on this figure are the complementary successional pathways for raised dry sites (the xerosere), which largely lead from coastal herbaceous ridge cover, for example, through forest and thicket, to swamp, to treed bog and, similarly, then to *Sphagnum*-dominated systems, based on gradual peat accumulation, the flattening of landscape gradient over time, and climate cooling, leading to landscape-scale paludification. While not the dominant succession in the region, this terrestrial-to-wetland succession has been documented in the Lowland by Sjörs (1963), McAndrews *et al.* (1982), Glooschenko and Martini (1983), and Klinger and Short (1996).

Puccinellia phryganodes intertidal marsh, southwest James Bay.

VEGETATION PATTERNS

MINERAL WETLANDS

Mineral wetlands dominate 90% of the 1290-km coast of Ontario's Hudson Bay Lowland (Glooschenko 1980a,b), and also occur along all of its major and minor rivers and streams, and as more minor elements on other terrain types. Along the coast it is the slope of the land that controls the width of intertidal marshes and the extent of high-tide inundation of supratidal marshes. Rising and lowering tides flow in and around the intervening beachridges thrown up on the emerging coasts by storm events. The widest expression of marshes is along the gently sloped coast of James Bay, and the same types occur along Hudson Bay, although they are horizontally compressed there by steeper slopes. Similarly, the width of meadow marshes along rivers is a function of the slope of the land away from the rivers, the size of the rivers, and the width of the flood-scour zone, with the widest riparian marshes occurring along major rivers with gently sloping banks, and around river islands.

Intertidal marshes dominated by *Puccinellia phryganodes*, and by *Carex subspathacea*, *C. glareosa* and *C. mackenziei*, can have dense cover varying from less than 5% to more than 90% shoreward. Its various associates all dominate their own series (App. A, B; Riley and McKay 1980). *Puccinellia phryganodes*, the coastal dominant, is an asexual saltmarsh grass that binds its clay substrates and has a circumpolar distribution based on stem breakage, ice rafting and shoreline currents. Shoreward, these wetlands can be arrayed as broad homogeneous marshlands, but they can also be arrayed in mosaic patterns of shallow ponds linked by narrow drains, flowing around raised *Puccinellia* swards, a pattern that is largely a function of ice rafting. Marsh vegetation becomes frozen into shorebound ice, and is lifted (rafted) off at spring break up by high tides, and relocated to other intertidal sites, or pushed up into supratidal sites or high-tide lines, or broken up at sea (Redfield 1972). The sites from which *Puccinellia* swards are rafted become the weakly vegetated pool phase of the mosaic pattern, separating the residual swards and dumps of lifted materials. Coastal waters can have salinities less than 1/2 to 1/3 of normal salt water, but pool-pannes can retain waters at low tide, evaporate quickly, and have elevated soil salinities as a result (Glooschenko 1980a,b). Salinity levels can also rise because ice rafts remove impermeable surface sediments, revealing coarser sediments beneath, in which upward hydraulic gradients can occur, resulting in hypersaline conditions (Price *et al.* 1988). Once established, this panne-sward pattern can persist into the supratidal zone, and beyond.

The pannes and swards support, as a result, a range of associations often dominated by single species, either emergent or submergent. *Eleocharis smallii* and *Scirpus maritimus*, for example, can form single-species stands with cover values from <10% to >80%. Shoreward, other species begin to dominate; such as *Carex paleacea* and *Potentilla anserina* var. *groenlandica*, among many, as species more typical of supratidal meadow marsh appear.

Panne-pools support obligate halophytes. Linear patterns can also be present, some indicating ice-rafting lines, while others suggest more subtle and less explicable parallel ribbing, perhaps associated with recessional strand lines or microtopographical waves as the coast rises and the tides withdraw.

The transition between intertidal and supratidal sites on the coast can be well defined by many of the parallel beachridges, which define the limits of normal tides. The rapidly rising coast throws up unique displays of parallel beachridges, made more complex by spits like Puskwuche and Longridge on southwest James Bay (tips of a bedrock-controlled moraine) that have beachridges splayed around their topographic spines. In some stretches, the coastline is uninterrupted by beachridges, and storm-tide or high-tide deposits of debris can then mark the boundaries between intertidal and supratidal sites. In supratidal sites above the normal tide limits (but subject to spring and storm tides), dense graminoids and shrubs dominate. Of the former, combined transect results show the dominance of *Festuca rubra*, *Eleocharis smallii*, *Carex paleacea* and *Juncus balticus*. Of these, the *Festuca* series dominates, predictably with cover values more than 50%, and often as a co-dominant in other meadow series. Coarser-substrate sites are dominated by *Juncus balticus* and *Calamagrostis stricta*, for example, and with more forb-rich associations than in intertidal marshes. Supratidal marsh pools and drains still have dominants such as *Carex paleacea* (often >80% cover), and shallow-water series dominated by *Eleocharis smallii* and others. *Potamogeton filiformis* and other pondweeds also dominates pools and pannes.

Supratidal marshes and meadow marshes are more species diverse. In these sites, the same coastal patterns of panne-sward mosaics and linear features often occur, but are often masked by rigorous vegetative growth, including thicket swamps and shrub-rich meadow marshes. Willow and alder thicket swamps dominate many of the transitions between open water and upland sites, and, in estuaries, can dominate broad flat areas, such as the species-rich thicket swamps dominating the southern part of Shipsands Island, in the mouth of the Moose River.

Estuarine patterns differ from coastal patterns. 1) The absence of beachridges parallel to the shores softens the distinctions between intertidal and supratidal situations. 2) Riparian erosion, especially by spring ice, results in heightened rivermouth diversity and more parallel-to-river patterning in the vegetation. James Bay's estuarine sites have similar dominants, such as *Carex paleacea* (>90%), and the floristic similarities are understandable, given the weak salinity of James Bay in general, and the weak effects of estuaries as a result. The pattern of tidal salinity in estuarine situations, such as in the mouth of the Moose River (Riley and McKay 1980), shows an upriver surge of cold saline James Bay water more or less confined to bottom strata and for only a short period at high tide. Estuarine sites differ from coastal sites in the absence of obligate halophytic vegetation. Uplift is such that marsh transects sampled only thirty years ago now appear to have shifted significantly towards their higher-elevation descendents.

The same marsh vegetation that dominates the James Bay coast also occurs along the Hudson Bay coast, but augmented with numerous subarctic species that dominate their own series; shrub wetlands dominated by *Salix brachycarpa*, *S. planifolia* and *S. glauca*, for example, and marsh dominated by *Carex subspathacea*, *C. glareosa* and *Dupontia fisheri* (App. B,C). Hudson Bay marshes tend to be smaller and more fragmented than on James Bay because of the denser hordes of beachridges that are packed more

Intertidal marsh at low tide, southwest James Bay.

closely together on the steeper grades. The inter-ridge transitions between ridge-marsh-pond-marsh-ridge can be tight, and have many phases that are transitional into peatland/tundra types completely different than any types along James Bay.

The rivers and streams along Hudson Bay have highly diverse riparian meadow marshes and thickets, more diminutive than at southern sites, and complicated by the presence of ground ice and of active layers of varying depths. For example, river levees can have the appearance of terrestrial conifer forest but with similar vegetation to conifer swamp. Underlaying some of these are frozen, laminated levee sediments (alternately ice and sediment), helping explain their similarities to wetland vegetation.

Farther away again from the coast, freshwater marshes increase, and organic freshwater situations develop, beginning the slow shift towards minerotrophic fens and swamps as water flow decreases and peat accumulates. Southward, sites can be dominated by *Typha latifolia*, with others dominated by *Carex, Scirpus, Salix, Menyanthes trifoliata* and *Utricularia vulgaris*. Willow and alder thicket swamps dominate many of the transitions to upland sites.

In coastal mineral wetlands, the major successional sequences are from marsh to meadow marsh, and from open water to shallow marsh and then meadow marsh. These sequences are most clear on the raised, sward phases of mineral wetlands, but are less clear for the panne-pool phases of mineral wetlands, which may fill in and become marsh, shallow fen or fen pools, depending on their water regimes. Regardless, it is notable that mineral wetlands, whether coastal or riparian, are highly disturbed by active depositional or erosional processes, such as the development of panne-sward mosaics, tide-mark lines, linear drawdown ribbing and ice-break-up scouring. As a result, they can change rapidly in their vegetation composition and in their internal drainage, and thus in their succession.

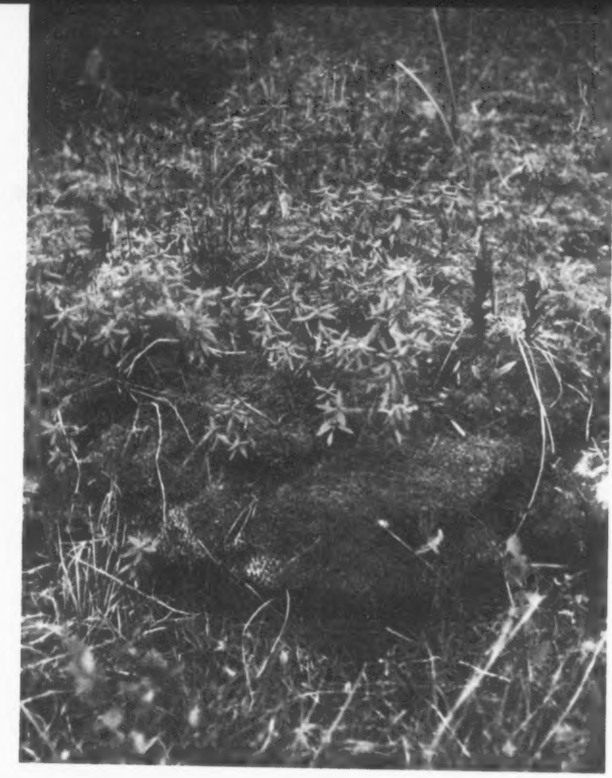
ORGANIC WETLANDS

Figures 18 and 19 illustrate the fundamental peatland successions. At the broadest of areal and temporal scales, the major sequences of succession are driven by deepening peat, which isolates surface vegetation from nutrient-bearing mineral substrates, and by increased effective surface dryness and surface-water acidity as a result. In summary, marsh succeeds to meadow marsh, meadow marsh to fen (or swamp), fen (or swamp) to bog and, climate dependent, fen and bog to palsa and/or peat plateau. Depth of peat increases, site dryness increases, and surface-water pH decreases.

Within these general patterns, it is worthwhile reflecting on three complementary trajectories. First, again, the sequence for deepening-peat types are predominantly from marsh and meadow-marsh, to open graminoid and shrub fen, and from fen to bog over time. However, the dominance of these types by trees, thickets and/or shrubs can vary at various stages along the way, in either meadow marsh, fen, bog or swamp, and can be reversible or alterable by either rising effective water levels, or by fire. Second, the pool-wetland sequences are less clear but appear to be from open coastal water and marsh (panne) phases, into interior freshwater shallow marsh, and to fen and bog pools, and other open water patterns within peatland complexes.

Third, seasonal and sporadic ice occurs first (and southernmost) under raised, deep-peat bog mounds (or islands, treed or shrub-rich), and under fen and bog pools. Northward, this seasonal ice becomes permanent under the same types first, and extends laterally under other *Sphagnum*-dominant sites (especially those with trees and shrubs), thus becoming a significant element of peatland patterning. The extent to which discontinuous permafrost helps define the netting of bogs and fens, and the terracing of string bogs and fens in the central Lowland is clear from peat probing but as yet understudied. Northward again, the role of permafrost becomes dominant, raising palsas and peat plateaus, and defining broad tundra fen plateaus and thermokarst peat plateaus, the latter lake systems driven by wind erosion downwind and by peat deposition upwind.

Another key driver is *Sphagnum* itself. First is its superior insulating properties, which permit frost and ice to be retained more durably and with significant expansion (and raising) of the peat profile. Second, *Sphagnum* actively binds available nutrients and thus acidifies surface waters in which it grows, modifying its habitat to favour its own growth and propagation (Shotyk 1988, Crum and Planisek 1992). Finally, *Sphagnum* peats are slower to decompose, which contributes to its enduring, "*climax*" role in wetlands like bog and peat plateau, unless they are set back by climate warming (or drying), permafrost melting, or wildfire.



Sphagnum bog encroachment onto marl fen, Kinoje Lake area.

Wetland succession has been called "*one of the classical examples of unidirectional plant succession*" (Sjörs 1963). However, associating the full range of peatland successions to the various multi-directional possibilities for succession, Sjörs coined the term "*polyclimax*" for the various intersecting successions at work in any particular wetland complex, which give rise to extremely diverse patterns in the Lowland (1961). Some of the successions he mentioned were:

i) At a local level, the hummock-hollow microtopography of some open ombrotrophic bogs, which may be engaged in a cyclic reciprocal-replacement succession;

ii) The local role of beaver in blocking drainage and drowning bogs, fens and thicket swamps, causing meadow marsh and marsh development, eventually reverting if abandoned;

iii) Ponds in peatlands can be secondary waterbodies independent of subsurface topography, but can coalesce and broaden to the extent that mineral substrates are contacted, with a possible consequent input of nutrients into the water regime of adjacent peat systems.

Sjörs had no helicopter support and thus had limited access to the full progression of wetland types (and patterns) from coast to interior, and we can thus add to his list of associate successions, in particular the subtle shoreline topographies — such as panne-sward mosaics, and semi-parallel ribs and channels — that may also underlay interior wetland patterns, *i.e.*, are perpetuated from coastal meadow marsh, through incipient fen, into interior peat systems. Thus, coastal geomorphological processes may help explain some interior patterns, such as channel fens (based on coastal inter-ridge channels) or bog and fen pool patterns (based on tidal ice-rafting and panne-sward mosaics).

Some of the recurrent and widespread peatland patterns of the area are still poorly understood; for example, the development of the "*string*" patterning in fens and bogs, in which terraced ribs and pools (*flarks, rimpis*) are oriented perpendicular to water flow. Hypotheses such as Hamelin's (1957) "*glissonage*" concept suggest that differential ice freezing and thawing may play a role in perpetuating this terracing (similar to polygon formation). Certainly, ice persists longest in ribs.

The successional themes indicated on figure 19 are also based on observations of sites that appear transitional from one type to another, or appear out-of-equilibrium or vestigial at a site:

i) Sites where fen indicators like *Larix laricina* and *Betula pumila* persist as mature individuals at low cover values but where bog otherwise prevails; the tamarack can be persisting as dead stumps or be visibly buried by *Sphagnum*. (The reverse, mature *Picea mariana* as remnants, alive or dead, does not occur in fens, though there can be *Picea* die-back by beaver-flooded meadow marsh.)

ii) "*Breakdown*" sites where treed bog or fen can be largely graminoid and in which trees are dead (by drying, acidifying in bogs, by rising water in fens).

iii) "*Incipient*" palsa sites where peat elevation through ice flotation is minimal and apparently only marginally successful on a year-to-year basis.

iv) "*Immature*" coastal fens where peat accumulation is low and meadow marsh species persist at low cover values, but with bog "*islands*" or bog "*pocks*" (or "*incipient*" palsas) also present.

v) Complexes where measured differences in peat depth and pHs between "*hummock and hollow*" or "*ridge and hollow*" suggest that fen and bog can coexist in such patterns more commonly in areas of low peat accumulation (coastward) than in interior sites with deep peat.

vi) Wildfire occurs almost exclusively on raised bog or bog-like palsa or peat plateau, and never in fen. (Some post-burn sites show heightened paludification as a result.)

vii) Swamp is usually confined to better drained sites, some of them affected by beaver to some degree; the resulting meadows and thickets cycle through the beaver-flood cycle, a short-term cycling within the longer-term Lowland successions.

PATTERN TYPES

A variety of complementary classifications of pattern in the Lowland have been based on the morphology and aerial display of wetland types (Zoltai *et al.* 1974; Tarnocai 1979; NWWG 1988:415-427; Riley 1994a:55-59; Mortsch 1990, Chap. 3). There are also unpatterned systems, which constitute a distinct pattern in itself. Thus, every wetland is patterned at various scales, usually involving multiple wetland types, successions and exceptions, and terms like the following have been used to describe some of the common patterns.

Raised Permafrost Patterns

- **Mounds and palsas** (fen, bog)
- **Peat plateaus** (bog-like plateaus with discrete hummock-hollow phases, i.e., raised mounds netted by interstitial drainways; fen-like plateaus without hummock-hollow phasing and not interrupted by notably deeper interstitial drains)
- **Polygon** (permafrost peatlands)
- **Margins** (shrub tundra fen or bog edges)
- **Pools** (fen, bog)
- **Thermokarst** (lakes from pond sizes to large lake sizes)
- **Collapse scars** (fen, bog, mound, palsa)

Plain or Plateau Patterns

- **Flat** (bog, marsh, meadow marsh)
  Panne-sward (marsh, meadow marsh)
- **Terraced and drainway systems**
  String, ladder, ribbed or feather (marsh, meadow marsh, fen, bog)
- **Pool-pond systems** (may also be terraced)
  Lattice or net (patterns of treed or open, shrub or graminoid; fen, bog, or fen and bog)
  Lattice or net (pool patterns, 10–90% open water, of variable sizes; fen, bog, pool, open water)
- **Islands** (treed bog, treed fen, swamp)
- **Margins** (conifer or thicket swamp, treed fen or bog, shrub fen or bog, tundra margins)
- **Unpatterned systems**
  Horizontal (swamp, fen)
  Sloping (swamp, fen)
  Channel (marsh, meadow marsh, fen)

Basin Patterns

- **Stream, floodplain or riparian systems**
  Alluvial (swamp)
  Riparian, and ice-scoured (marsh, meadow marsh, thicket swamp)
  Stream (marsh, fen, swamp)
- **Floating or shore** (marsh, fen, bog, swamp)
- **Basin** (marsh, fen, bog, swamp)
- **Sinkhole** (meadow, fen or bog)
- **Seepage** (marsh, fen)
- **Kettle** (marsh, fen, bog, water)
- **Beaver flood** (marsh, meadow marsh, fen, water)
- **Flat** (marsh, meadow marsh, fen, bog, swamp)

WATERFLOW, HYDROLOGY and TOPOGRAPHY

A primary determinant of wetland vegetation, pattern and succession is waterflow, which is influenced by local topography, however minor. The Lowland has innumerable watersheds and mapping them presents many challenges. This is particularly obvious along any major river. A field worker along the central Attawapiskat River, for example, would be comfortable with the similarities of that river, in terms of flow rates and seasonal hydrology, to its Canadian Shield analogues, but such comfort would only extend to the immediate, adjacent riparian and levee systems. A kilometre beyond the river puts a field worker on a marine clay plain supporting deep peat systems within which the lateral flow of water is measured in decades, not seasons, and in which direction of flow may be, in fact, away from the closest down-cut river. As a result, the Lowland can be viewed as having two distinct hydrological systems: one, the high-energy, high-flow systems of major down-cut, flow-through rivers and coastal tide zones; and two, the low-energy, low-flow systems of the dominant clay-plain peatland systems. The two are distinct in vegetation and other biota, and in succession and ecological processes.

Coastal systems have surficial microtopographic patterns that are the result of water drainage through and across surfaces such as panne-sward mosaics, tide-line breaks, parallel ribs and inter-ridge drains, features that drain or block water with variable efficiencies. Their variable drainage efficiency likely influences their seasonal (and multi-year) water storage and, as a result, their organic accumulation. Nevertheless, coastward and near rivers, all water, whether groundwater, precipitation or flow-through from the Shield, are in direct contact with non-Shield mineral substrates and are thus richer in available nutrients than the waters of deep-peat systems on the clay plains and till plateaus of the Lowland. By contrast, in peatland systems, water flow and the variability of water level and nutrient availability, is based more directly on local precipitation and evapotranspiration, and the water-retention capacity of peat itself.

Lowland peatlands likely retain a volume of water equivalent to the volume of water in Lake Erie or Lake Ontario. The turnover period for the water in Lake Ontario is six years. For the Lowland it is likely many, many centuries. No longitudinal studies have been conducted of wetland water-retention rates or the movement of water in

Lowland peatlands. One of the few regionally relevant hydrological studies was in the Kennedy Bog complex, northeast of Cochrane (Dai 1971, Dai *et al.* 1974). Over the course of one summer (mid-June to mid-September), the level of waters in lakes varied within a range of 10cm; in conifer swamp within 16cm; in treed bog within 16.5cm; and in open bog and poor fen within 10cm. Thus, in absolute terms (based on depths from substrate), water depths varied by 6 to 14 cm over the summer. Depths increased immediately after rain events, lowering slowly thereafter. By mid-September, water levels were not significantly different from those in mid-June. Based on this study, in an area of higher evapotranspiration rates, overall water retention was still positive and stable, favouring peat accumulation as a result.

What influences wetland vegetation is the position of a water table relative to the surface vegetation, not its absolute depth, and there are mechanisms that help stabilize the relative water levels in some systems, such as fens, despite significant annual or seasonal changes in absolute water volumes in a system. For example, fen peatlands float to a considerable degree; at Kinoje, a 90cm difference in absolute peat depth was recorded from one wet year's freeze-up to the next (dry) summer and autumn, without evidence of any significant change in relative depth-to-water in the fen (pers. comm., H. Lumsden, formerly OMNR Wildlife Research). The laminated graminoid peats that underlay open fens can physically expand and contract more so than the fibric *Sphagnum* peats of bogs, and can maintain more stable water-level relationships than other wetland types. Fluctuating, relative water levels are of most consequence to vegetation succession and carbon sequestration (and emissions of methane), but it is likely that absolute water levels, affected by climate and evapotranspiraton rates, are of most consequence to retaining stored carbon overall.

The Kennedy Bog study also mapped its waterflow directions, out of the peatland into lakes and drainways, which were themselves the deepest topographic depressions in the area even though they too were deeply covered with peat and muck. Such subsurface topography, and even the more subtle microtopography northward in the Lowland, is a key determinant of drainage and of vegetation, whether in coastal panne-sward mosaics, inter-ridge drains or subtle downslope ribbing, or where the same topography underlays interior fens or bogs.

"*The direction of water flow is always easy to determine in patterned peatland, being at right angles to the ridges and depressions, which are thus parallel to the contour curves*" (Sjörs 1963). This holds true in subarctic peatlands globally, both in bogs and fens. A corollary of this is that the elements of a pattern that separate peat depressions, (raised ribs or strings or mounds that separate low pools or open fen or bog) are, in effect, markers of slight differences in surficial elevation, a subtle landscape terracing. The terracing can be almost imperceptible, so much so that differences in the persistence of grounded or buoyant ice (year-round or seasonal) may also determine patterning. Sjörs measured water-level drops as high as 26cm between consecutive bog pools in a patterned bog in the central Lowland. In a ribbed (string) fen in the same area, however, he counted the number of flarks (graminoid or pool fens) as 200 to the mile, and calculated each adjacent terrace drop at about a quarter of an inch, about 0.5cm (Sjors 1963).

Water movement itself is of consequence. Water movement itself effectively makes nutrients more available to vegetation, thus influencing vegetation pattern, deposition and peatland topography. Water movement is an indirect factor influencing the concentrations of iron, manganese and aluminum in surface waters (Dai 1971). As a rule, the lateral flow of water is least in bog, greater in fen, and greater still in marsh and meadow marsh.

Finally, the seepage of groundwater out of raised subglacial deposits, beachridges and river banks enhances available nutrients, particularly calcium, in downstream systems. In the Lowland, nutrient-rich calcareous marl fens can be the result, and also the beneficiary of longer growing seasons as a result of the high-lime substrates, with regionally anomalous high species diversities as a result. Along riverbanks and lakeshores, the same groundwater seepage gives rise to minerotrophic systems such as swamp, meadow marsh and marsh.

PEAT STRATIGRAPHY

Wetland succession and pattern are most directly interpretable from studies of peat stratigraphy, or peat-cores or lake-cores, which have been done only rarely in the Ontario Lowland. Jeglum and Cowell (1982) cautioned that the "*elucidation of successional pathways required more detailed study of stratigraphy.*" In the field, this interpretation of peat stratigraphy can be done by visual inspection of peat in the hand,

which can help interpret peatland succession at a site. First, the association of the immediate surface vegetation with its surficial peat warrants confirmation, followed by the observation of the succeeding, discrete, underlaying intervals of peats of various origins, based on visual and tactile inspection of fibre composition and peat decomposition. For example, a dominant *Sphagnum*-moss peat normally indicates bog conditions at the time of deposition, and increasing levels of woody peat indicate a treed or shrub condition. Dominance by brown-moss peat or sedge peat normally indicates fen conditions at the time of decomposition, with increased amounts of mineral materials indicating marsh and meadow marsh peats.

Basal sediments indicate particular deposition environments. By far the dominant substrates underlaying Lowland wetlands are marine clay, clay, clay till and silty clay till (and lacustrine clay). Rarely, other substrates were encountered, (which may themselves be underlain by clay sediments), including sand, fine sand, sandy silt and silt. Only very rarely were typical aquatic substrates encountered, in restricted infill basins on highlands; mostly *gyttja*, the white-green-grey-brown substrate with diverse plant and animal remains indicating a nutrient-rich deposition environment. More frequently, and adjacent to raised deposits, were basal marls made up of charophytes and other carbonate materials, indicating calcareous groundwater influence at the time of deposition. Also occurring as basal peats are, occasionally, hard, woody forest-swamp peats indicating drier earlier conditions, and resisting sampling, even breaking off auger heads, such as near Jog Lake in 2009 (others also report similar initial forest-swamp periods; Sjors 1963, Klinger and Short 1996). Seeds and other identifiable indicator plant materials can also be present (Riley 1994a). While wetland initiation elsewhere is often associated with aquatic environments, Lowland wetlands are almost all initiated directly as marsh and meadow marsh.

However, at the regional scale, the substrates underlaying Lowland wetlands do little to differentiate them because they are so uniformly clay- or silt-based, and impermeable throughout (Tables 2-4). The peat accumulating on that substrate, however, is also generally predictable. Generally, the lower stratum is basal sedge peat, followed (upward) by a period of sedge, shrub and brown moss (and occasionally tree wood), overlain by *Sphagnum*-dominated peats (Klinger and Short 1996). Similarly, the gross stratigraphy under large wetlands south of the Lowland, in northeast Ontario (ecoregion 3E and south), show comparable general patterns (Riley 1994b). Under treed and open bog systems, the top quartiles of peat were comprised of 75% to 99% moss peat respectively (peat pH 4.4, n=20, and pH 4.4, n=74, respectively). The lower quartiles of peat contained 31% and 28% sedge peat respectively (peat pH 5.9, n=12, and pH 5.9, n=55), illustrating the succession from sedge to moss, and to increased acidity. Under treed and open fen, however, the percentage of sedge peat was consistent from lower quartiles to top quartiles (average 30%, n=100), illustrating their enduring stability over time.

In 1957 Sjörs sampled a cross-section of a palsa west of Hawley Lake, illustrating its raised, continuous frozen core and its ice-lens bibs (1961). Ice expansion had raised its surface more than 1m, and its total thickness was 4m over clay. Sjörs also sampled (1963) a 1.3m peat core from the central Lowland (Muketei-Attawapiskat area), observing 1m of *Sphagnum* peat over 30cm woody fen peat, over marine clay with arctic mollusks. Terasmae and Hughes analyzed its pollen, which was dominated throughout by *Picea*, but with basal foraminifera and high sedge (*Cyperaceae*) pollen counts indicating its saltmarsh origins (1960). The lower level had a peak in *Betula*, an indicator of a shoreline or shrub phase, progressing upward into peat relatively abundant in *Ericaceae* and *Sphagnum*, indicating the succession to its modern bog stage. The basal peat was dated to 4700 ±80 yBP, at elevation 114m ASL. Sjörs interpreted emergence from the sea, and transition from marsh, through fen to bog. He also cored another transect across the draining edge of a treed bog, also illustrating its stratigraphic progression from cool coastal conditions (with indicators like the moss *Drepanocladus tundrae*), up through woody fen peat, through *Sphagnum* peats, to its modern black spruce bog. A major, modern riparian burn layer was also noted.

In July 1978, the author assisted in coring the Pipowitan peat plateau, a raised palsa field, or lichen-rich peat plateau, as coalesced palsa fields are termed (55°59'N, 88°48"W). It had a 25cm active layer, overlying 3.1m of peat, overlying at least 5cm of frozen clay. Pollen and spores from its lowest 10cm were dominated by sedges and grasses, indicative of its origins as a mineral wetland, and its middle 10cm was dominated by *Sphagnum*, *Picea* and a variety of shrubs, indicating the shift towards bog. Its top 10cm of frozen core was completely dominated by *Sphagnum*, *Picea* and ericaceous shrubs. There were no alternating patterns of peats in the core that might suggest any cyclic patterns of peat growth and deflation, or burning.

The vertical stratigraphy underlying topographically-defined lakes also reflects successional history, because they preserve fossil deposits that illustrate succession in the vicinity of a lake. A high-elevation lake-bottom core was sampled in 1980 at 145m ASL at R Lake, southwest of central Aquatuk Lake (54°19'20"N, 84°33'30"W, McAndrews *et al.* 1982). Its 450-cm lake-bottom core was the first such sampled from the Ontario Hudson Bay Lowland, and its fossil strata parallel the temporal succession of vegetation inland from Cape Henrietta towards the Sutton Ridges, on which the R Lake is perched. The lake was first isolated from the Tyrrell Sea about 8200 yBP, at which time coastal indicators in the core included *Plantago maritima*, a coastal obligate, and *Potamogeton*. The initial upland vegetation was a sparse tundra dominated by *Dryas*, willows, grasses and sedges. With gradual uplift, shrub birch came to dominate the tundra, along with heaths and *Shepherdia*. Subsequent rebound reduced the influence of the cold sea, permitting spruce, tamarack and poplar forest by about 6500 yBP. The Sutton Ridge ceased to be an island around 5000 yBP, and a warmer climate at that time is indicated by the presence of *Najas flexilis* in the core, whose nearest modern occurrence is now south of the Lowland entirely (Riley 2003). The subsequent decrease in tree macrofossils, and increase in *Sphagnum* after 2500yBP, indicate both modern neoglacial cooling and widespread regional paludification.

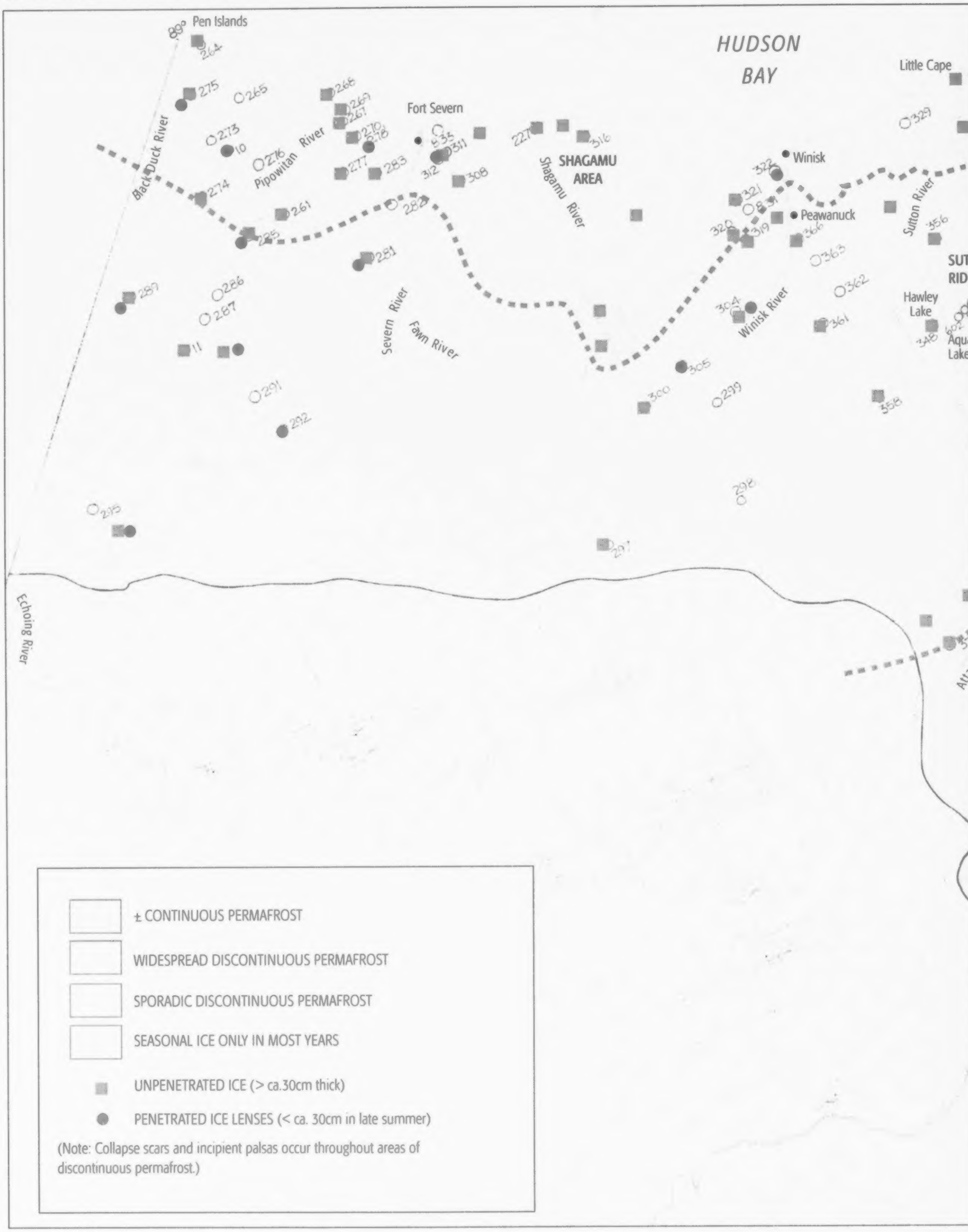
In 1990 Klinger and Short sampled a peat column from near Kinoje Lake (1996). The basal peat, 2.8-2.4m deep, was dated to 4110 yBP to 3400 yBP, and had the maximum values for grasses, sedges, willows, *Artemesia*, chenopods and *Equisetum*, analogous to modern coastal dominants. Large pieces of wood denoted the presence of tree cover at this time. The overlying strata, from 2.4-1.2m, was dated to 3400 to 2400 yBP, and had ericaceous shrubs, birch and alder taking over in dominance, and *Sphagnum* increasing to moderate levels. The peat strata above this, from 1.2m to surface, dated 2400 yBP to present, was dominated by the maximum values for *Sphagnum* and for ericaceous shrubs, and minimum values for herbs in general. Wood remains were absent. They also noted the dramatic increase in *Sphagnum* pollen after 2000 yBP and associated it with regional paludification. (*Picea mariana* pollen was consistent throughout the peat column. at 20-60%, and not indicative of local variation in tree cover.) Klinger and Short also surveyed the vegetation between Kinoje Lake and North Point, which paralleled in many ways, longitudinally, the stratigraphic succession that they had documented vertically (further discussed below).

PERMAFROST

Permafrost is a powerful determinant of Lowland ecosystems, and underlays almost all vegetation types, even terrestrial sites, in the maritime tundra zone within 100km of Hudson Bay (Fig. 20; ±continuous permafrost, ±ecoregion 0E), and discontinuously in an even larger area to the south. It is notable how few observations of permafrost have been assembled systematically, considering the broad extrapolations that may have to be made from such few data in a period of rapidly warming climate. To this end, descriptive terms such as palsa, peat plateau, thermokarst and tundra fens have particular value in surveys, so that the distribution of permafrost features are secondarily documented through its dependent vegetation. Figure 20 indicates the limits of more or less continuous permafrost, the extent of widespread but discontinuous permafrost, and the southern limit (approximate) of sporadic discontinuous permafrost. Generalized mapping is problematic, so point-observations are mapped, for: 1) impenetrable ice (resistant to stainless steel rods and therefore >ca. 30cm thick) and field observations of peat plateau; and 2) penetrable ice (penetrated by steel probes and thus found to be generally <30cm thick, ice lenses). In this regard, it is worth noting that collapse scars and other collapse features, and incipient palsas, occur throughout the zones of both widespread and discontinuous permafrost.

Along Hudson Bay, permafrost also occurs under beachridges, river levees and other terrestrial sites (Brown 1973). Ice can be reached quickly by digging in a beachridge in ecoregion 0E. Near the coast, many of the lower river levees consist of alternating strata of alluvia and ice, and are high and dry enough to support tree growth even though they are underlain by permafrost. Southward, these levees grade into ice-free conditions, in a north-to-south transition.

Permafrost dominates the peatlands between the rivers in ecoregion 0E, underlaying all systems. Southward, in ecoregion 1E, frozen peatland mounds (palsa) and ribs and islands are the most diagnostic permafrost features. Permafrost persists longest southward in ecoregion 2E in its deepest peats. The growth of raised *Sphagnum* hummocks (bog vegetation, especially *S. fuscum*) results in increased winter exposure and internal freezing, and the seasonal durability of that ice is extended by the superior insulating qualities of *Sphagnum* itself, which can be further consolidated by an increase in *Cladina* lichen cover (preferring higher, drier sites sites) which, in turn, cools the peat by raising albedo and furthering ice accumulation.


HUDSON
BAY
Pen Islands
Little Cape
Fort Severn
Winisk
Peawanuck
SHAGAMU
AREA
Black Duck River
Pipowitan River
Shagamu River
Severn River
Fawn River
Winisk River
Sutton River
Hawley
Lake
Echoing River
± CONTINUOUS PERMAFROST
WIDESPREAD DISCONTINUOUS PERMAFROST
SPORADIC DISCONTINUOUS PERMAFROST
SEASONAL ICE ONLY IN MOST YEARS
UNPENETRATED ICE (> ca.30cm thick)
PENETRATED ICE LENSES (< ca. 30cm in late summer)
(Note: Collapse scars and incipient palsas occur throughout areas of discontinuous permafrost.)

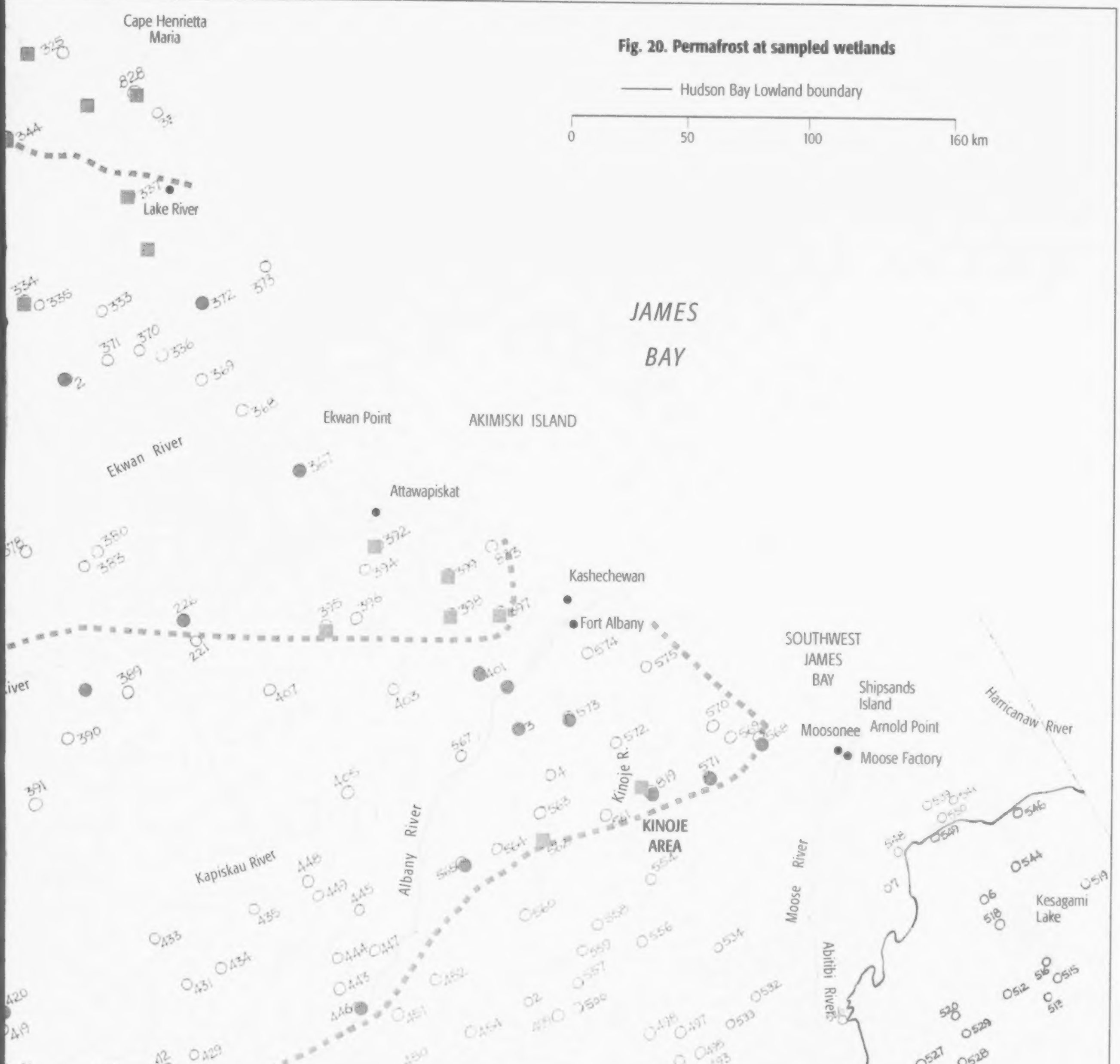


Fig. 20. Permafrost at sampled wetlands

TOP. Ice-wedge polygons forming in shallow peat, Cape Henrietta Maria.
BOTTOM. Circular ice-collapse scars, inland near Swan Rive, James Bay.

Upward flotation of such ice and consequent lowering of effective water levels also increases the insulating capacity of overlying peat (by drying it), preserving ice through hot summers, and encouraging *Cladina* growth.

Raised palsas occur in the threshold zone in which the growth and degradation of permafrost are in balance, most notably in ecoregion 1E. A study of palsas west of Hawley Lake by Railton and Sparling (1973) suggests that palsas are growing and collapsing there on a continuous cycle of as little as 200 years, based on the climate at that time. They also note the role of *Cladina* and *Sphagnum* in raising albedo levels, resulting in a negative heat balance and thus preserving and expanding the contained ice-peat, raising it to an elevation limit beyond which rain and runoff remove the lichen cover and erode channels down the palsa slopes. The palsa can thus collapse as a result of changing surface-volume relationships, in that the ultimate height and exposure of a palsa initiates its own runoff and rain erosion, thus undermining its insulating active layer, followed by calving-off of palsa edges. The collapse scar reverts to graminoid bog or fen, or pool. Other collapse features include tipped trees and relict collapse pools. (Zoltai and Tarnocai (1971) drilled comparable Manitoba palsas.)

North of this, in ecoregion 0E, the palsas coalesce into palsa fields or peat plateaus, which cover broad plains at peat depths that can grow to 3m. and more. North of Hawley Lake, side-slope erosion off permafrost peat plateaus is no longer at play, and the thermal effects of albedo are more widespread, rather than at the scale of individual palsas. The effective difference in albedo between *Cladina* and *Sphagnum* surfaces may not be significant, given that wildfire, which often burns off lichen-rich peat plateaus, especially westward, does not result in significant collapse of peat plateaus (the lichen burns off, revealing the underlaying *Sphagnum* and other mosses). However, field observations also suggest that caribou grazing on lichen-rich peat plateaus (now much reduced from historic levels) may also remove lichen to the degree that darker heat-absorbing peats are revealed, leading to melt-out and to pools in slumped peat basins (site 261). Thus, the factors explaining collapse features can extend beyond climate, to biological factors.

The surface vegetation of permafrost peat plateau can be either bog-like or fen-like. The former is dominated by lichens, ericaceous shrubs, and either without trees or with black spruce, and is patterned in a hummock-hollow phasing; hummocks raised 1m or more above ambient landform, with lower interstitial drainways among them, organized in net patterns across bog-like peat plateaus. Elsewhere, however, peat plateau can be low-diversity graminoid fen dominated by *Scorpidium* spp., *Tomenthypnum* spp., *Carex rariflora* and other black mosses, on raised and unpatterned permafrost plains, with minor (if any) interstitial drains. These have uniform active layers of 20-35cm over frozen peat, and ice-wedge polygons can be found in

them in shallow-peat coastal sites. Fen peat plateaus are not a well documented peatland type, and have called, in Ontario, *coastal fen* by Brokx (1966) and Bates and Simkin (1969), and *tundra fen* by others.

Peat plateaus support another cyclic successional sequence, thermokarst lake systems. Large coalesced bog ponds and lakes (secondary water bodies) migrate across the peat plateau in the direction of prevailing winds (to the southeast), by a process of wave erosion of the permafrost downwind and deposition of eroded peat on the upwind sides. The thermokarst lake systems 90km west of Peawanuck are the most mature and extensive in the Ontario Lowland. In some areas the thermokarst lakes occupy more than 50% of the landbase, such as in the area between Shagamu Lake and the Winisk River. Climate warming will change the cycles and the periodicity of permafrost development and erosion in this and other permafrost systems and, in this regard, it it worth noting that, even though the present successional patterns are in balance with current climate and topography, they have evolved over millennia of climate change and have been stratigraphically superimposed on peatlands that were themselves the products of succession in other climates, such as the warmer climates and better drained conditions of the Hypsithermal Period, followed by a period that was, in turn, cooler and wetter than today.

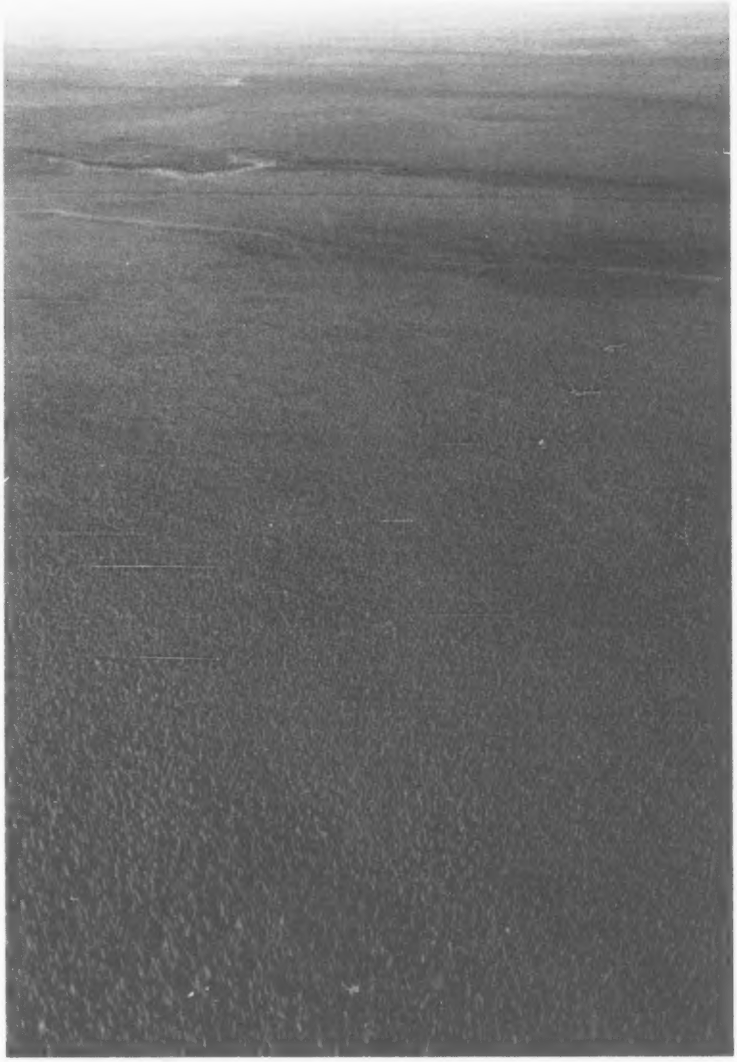
Farther into the interior, the flat graminoid tundra fens show permafrost mounding, with low palsas forming within them, raising themselves as black moss mounds scattered through fens. Their development is associated with the deeper accumulations of peat towards the interior, and can be associated with the same permafrost processes that results in frozen mounds such as pingos elsewhere in the arctic. They appear to follow the same fen-to-bog succession, in this case, of fen-like peat plateau to bog-like peat plateau. At other sites, such as 60km south of Little Cape, they can also take the form of species depauperate, lichen-rich, prostrate shrub tundra.

Most notably in the central Lowland, there is a developmental relationship between black moss pools (in both bogs and fens) and incipient permafrost, but the relationship is unclear, and likely involves water reflectance (albedo) and the insulating capacity of peat (Cowell *et al.* 1978). These pools can occur southward, also with very characteristic black moss signatures, and can host floating permafrost ice lenses. They may be permafrost collapse features in some places and permafrost growth features elsewhere, retaining summer ice more efficiently than their environs. Such pool phases become more dominant, with larger and larger pools, towards the southern interior, where they can make up more than 20-30% of a fen complex. Areas between ponds can be shrub-rich fens or tamarack treed fens on raised ribs between pools. When ponds exceed 30-40% of a fen complex, in particular, the terrain takes on a lattice, or net, pattern of reticulate ponds and ribs, sometimes organized perpendicular to water flow (and slope) but most often less linearly organized. These terraced pool systems have been variously called *polygon* fens (misleadingly) by Bates and Simkin (1969) and, better, *net fens* by Zoltai (1988). To date there has been little systematic probing for ice under these net fens but ice does occur near the surface in the ribs and a net-like topography of ice may well frame a net fen, patterned in relation to the different insulation characteristics of the different wetland types. Pools also freeze, expand, crack, infill and re-freeze more readily than peat (rib) columns and can expand horizontally to exert lateral pressure against the shores of pools, further defining and raising the raised or hummock ribs that separate pools in lattice or net patterns (Sjörs 1963).

Overall, the occurrence of permafrost decreases southward, as both spatial and temporal discontinuities gradually disrupt it. Extensive frozen peat plateaus dominate areas within 90km of the coast, and can also occur as smaller peat plateaus and discrete palsa patterns south to the Attawapiskat River. Again southward, permafrost persists in its most southerly situations as discontinuous ice lenses in raised bog islands, in elevated ribs, and under bog or fen pools. These occurrences are set amongst non-permafrost peatland mosaics, as far south as the Albany River basin and beyond, where the permafrost thins out and persists as ice lenses as little as 30cm or less thick in late summer, and under a decreasing number of wetland types. However, even south of the Albany River, such as in the Kinoje Lake area, frost can persist continuously, down into underlaying substrates (Cowell *et al.* 1978), and in rare cold summers, ice can persist even farther south from one year to the next (Kirkconnell 1919).

Overall, James Bay has a cooling effect that pushes southward the occurrence (and increases the frequency) of impenetrable peat ice (Fig. 20), but it is also clear that ice lenses and other spatially discontinuous permafrost can also occur far into the interior of the Lowland and westward beyond it, in deep peats.

Treed fen, northern Moose River basin.



Location Sequences

Wetland patterns and successions occur at local and sub-regional scales, and can best be described at particular locations. Sub-regional descriptions are also helpful, for conceptualizing the general north-to-south variation in wetland formations across the Lowland (Fig. 21). Figure 21 percentages to the south are based on Northern Clay Belt calculations by Jeglum and Boissonneau (1977), and reference has also been made to the proportions reported by Ahti and Hepburn (1967). On Figure 21, there is probably an exaggeration of the proportion of non-wetland uplands, estimated at less than 10% for the Lowland as a whole (Ketcheson and Jeglum 1972; Sims *et al.* 1979). Permafrost is represented by shadings super-imposed on the major formations in which permafrost occurs in different parts of the Lowland, with peat plateau assuming a dominant role to the north.

SOUTHERN JAMES BAY

At south end of James Bay, topographic gradients are extremely shallow, and the extent and width of coastal marshes are continentally anomalous. Farthest offshore are *Zostera* and *Potamogeton* beds, and the initiation of intertidal *Puccinnellia* marsh is very gradual. High-tide lines, beach-ridges and spits mark the topographic limits that delineate the borders between wetland types and allow for sediment and organic accumulation in lower-energy supratidal environments (Glooschenko 1980). In general, the further succession towards interior wetlands is of two types.

First, in the vicinity of the Moose, Harricanaw, Partridge and Missisicabi Rivers, there are broad supratidal meadow marshes, and open shrub-rich freshwater marshes and thicket swamps, arrayed on slight microtopographic rises and dips parallel to the shores, above the wide intertidal marshes and mudflats (Riley and McKay 1980, Price *et al.* 1988). Above these, freshwater marsh grades into open and treed fen, with conifer swamp and levee broadleaf and conifer forest along the rivers into the interior. Between the rivers are some relatively elevated points, such as Halfway, Longridge, Piskwanish, North and Natatishee Points, where upland thicket and conifer forest can occur immediately above the tidal marshes. At Natatishee Point, for example, open bog occurs closer to the coast than elsewhere (at 80°01.5' W), due to the unusually high elevations close to

the coast and the duration of peat accumulation as a result. Behind these elevated areas, deeper peatland complexes dominate, both independently patterned (80°10'W) and stream-ordered (80°20'W). South of Natatishee Point, patterned bog and fen complexes dominate, close to the coast, as they also do on the raised moraine between the Moose and Albany systems, which extends to the coast at North Point and Longridge.

Second, the most homogeneous drainage system in the James Bay lowland is the Moose basin where, uninterrupted by beachridge terracing, hundreds of relatively parallel streams all drain to the Moose and Missinaibi Rivers. The slopes are sufficient to inhibit bog development and flat enough to result in an extraordinary uniformity of treed fen between streams, and of thin swamps and treed bogs along the streams. At some distance towards the interior, on these same slopes 40km west of Shipsands Island (51°20'N, 81°W), treed fen gives way to broad, open and relatively unpatterned bogs, but these are a small fraction of the overall fen landscape of the Moose basin.

A transect west from North Point to Kinoje (Kinosheo) Lake illustrates the intermediary sequences. At North Point, broad intertidal and supratidal marshes are segregated by upland beachridges from the higher freshwater marsh (see also Klinger and Short 1996:175). Peat depths increase rapidly towards the interior, although thicket and conifer swamp still lines the margins of streams. Peat depths regularly exceed 30cm at about 2km from the coast (*ibid.*)

Fifteen kilometres west of North Point, the coastal treed fens (of the Moose basin type) begin to shift to open fen, such as at 51°27.5'N, 80°40'W, where the open fen is dominated by graminoids (80%) and pools (15%), with an initiation of open and treed bog islands (5%). Peat depth is ±0.7-0.8m, surface-water pH 5.3-5.5, and the overall tone of the wetlands is defined by the the brown moss *Scorpidium scorpioides*. Basal peat here is dated at 1090±70 yBP (Klinger *et al.* 1994).

Farther inland again, at 27km west of North Point (51°32'N, 80°58.5'W), open graminoid fen (65%) and pools (15%) still predominates, with open lowshrub fen (10%) and a distinct increase in open and treed bog islands (15%). Bog islands appear, by comparison with coastward sites, to be spreading and coalescing. At the same time, the pool phase of the fen pattern, a minor component coastward, begins to exceed 15%, and the pools begin to link together. The peat depth has increased to ±1.3-1.8m, surface-water to 5.4-5.6, and the basal peat here is dated at 1960±70 YBP (*ibid.*). The overall tone of the landscape is still set by the dominant brown moss *Scorpidium scorpioides*.

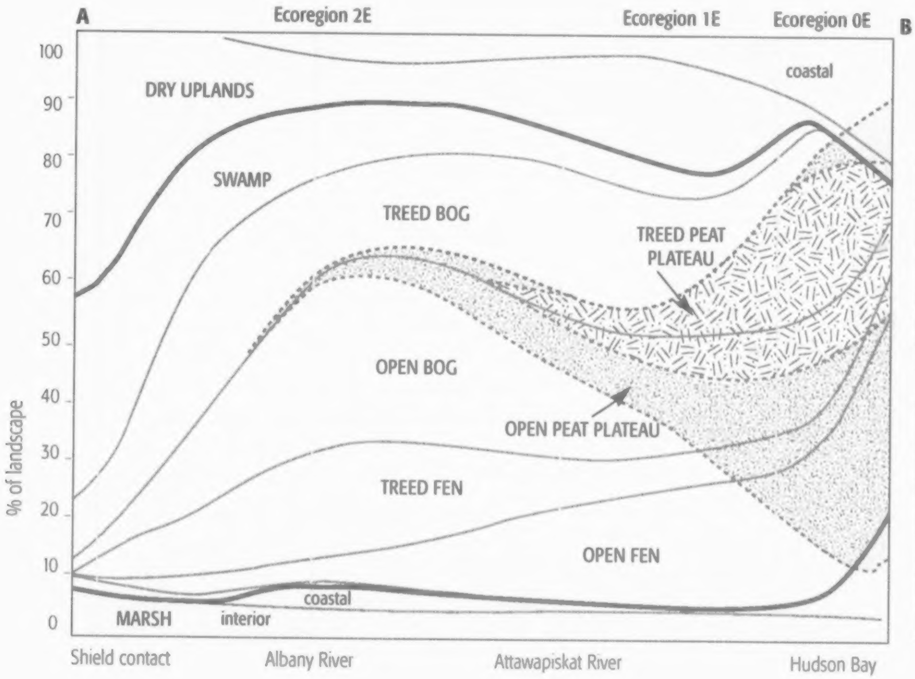
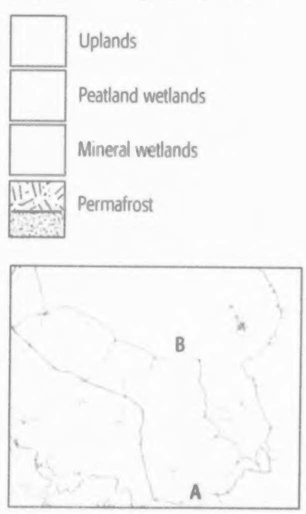


Fig. 21 Generalized south-to-north vegetation changes (Riley 1982)



Expansive, flowing bog and fen complexes on the elevated Kinoje Lake plain.

The overall successional sequences in the Kinoje area have been outlined by Jeglum and Cowell (1982). Along flowing lakes and streams, where wetlands are influenced by seasonal water flow and the peats are shallow, one successional sequence occurs; shallow marsh, to meadow marsh, to thicket swamp, to conifer swamp. Alternatively, this sequence can succeed to treed bog, either with ice lenses or not. In areas where there are broad expanses of peatland not subject to water-level fluctuations but still in contact with mineral soil water, another sequence occurs; pool fen, to graminoid fen, to shrub fen, to tamarack or cedar treed fen. Pool fens can be underlain by ice lenses, so the sequence can also proceed, in the presence of ice, to bog, and in its absence, to conifer swamp. Finally, there is the bog sequence; pool bog, to *Sphagnum* or graminoid bog, to lowshrub bog, to treed lowshrub bog. Treed bog can also have ice lenses, elevating it above grade and enhancing it as effectively the driest of peatland types in the area (*ibid.*). These sequences help explain vegetation patterns, but their interpretation in the field is always enhanced by looking at peat stratigraphy; another sequence is that a site can begin as a forest or swamp and, through paludification (and a flattening of topographic grade), become wetter (such as in fen types), and then drier again as raised bog develops. Calcareous, open, species-rich fens also occur at Kinoje, where there is groundwater discharge directly southeast from the main raised ridge, and direct local paludification as a result, as growing acid *Sphagnum* physically rolls out over and buries alkaline marl fen (Cowell and Riley 1979) (photo page 61).

KINOJE (KINOSHEO)

Another 40km west, 100km from James Bay, is the Kinoje Lake (Kinosheo Lake) area, where basal peats 2.9m deep are dated to 4110±80 YBP (*ibid.*). Kinoje and Carling lakes lay on the clay-mantled till plateau separating the Moose and Albany basins. They surround a major arcuate ridge that is the height of land between the Albany and Moose rivers, a subglacial deposit that was re-worked by storm and wave while it was an island in the Tyrrell Sea (Cowell and Riley 1979). The plateau has been emergent >4000 years above the sea, and has succeeded to a bog plain. Its dominant wetlands are treed bog (38% of area), open bog (22%), treed fen (15%) and open fen (10%), representing the mature successional stage of peatland development in the southern Lowland (Pala and Weischet 1982, Klinger and Short 1996). Bog islands, strings, pools and mounds are the major pattern elements. Kinoje is a preferred nesting location for the Canada Goose, and fen and bog pools with raised peat islands and mounds in them are preferred nesting sites (Raveling and Lumsden 1977). This is an area of sporadic permafrost, which can influence succession even this far south: in a study in August 1976, 19 of 52 sampled peatlands had frozen lenses, averaging 52cm deep, several of which could not be penetrated (Cowell *et al.* 1978).

ATTAWAPISKAT

The classic Lowland survey was conducted in 1957 by Hugo Sjörs, his wife Gunnel, and Erling Porsild in the vicinity of the confluence of the Muketei and Attawapiskat Rivers (Sjörs 1963). The following successional sequences are described in their work, based on the many "*factors (types of drainage, trophic factors, corrosive oxidation, ice expansion pressure, frost upheaval, etc.) that are at work, forming and arranging the elements of the pattern*" of a peatland. Among the ombrotrophic types, there are extensive areas of open bog, often patterned with pools and ribs. Bog also regularly occurs as elevated islands, which are usually clearly delimited and usually

with ice cores and often with permafrost black spruce islands. Almost all the bog systems are patterned with pools, much larger than their equivalent bog "hollow" pools coastward and often the dominant type in bog systems. Bog hollows still occur, but at finer scales in comparison with the very large ponds that can dominate these systems. Ice lenses in bog pools, followed by a buoyant uplift of frozen peat lenses as peat masses in open pools, have been observed (buoyant enough to support the author), and Sjörs also noted such floating ice lenses. He also noted how the process of ice expansion by pools reinforces the raised-rib vegetation that separates the pools. In deep bogs north of the Muketei, the pools expand into ponds and lakes, and the lakes show the same patterns of down-wind erosion (into the bog) and up-wind deposition that become, northward in permafrost peat plateaus, thermokarst systems (*ibid*, p.124-125).

Among minerotrophic types, fen is frequent in the form of seepage drains delivering bog waters to drainage outlets. They also occur, however, as flat fens within which are embedded miniature raised bog islands. As in the Moose River basin, the central Attawapiskat also has distinct basins with parallel streams and brooks flowing down very regular slopes, across very even substrates, and these basins are predominantly fen, often treed and rich in shrubs, including alder, birch and, even, cedar. However, between the parallel rivers and brooks, elevated bogs develop and can be miles long and very narrow, and raised (domed) in cross-section. Some of these areas of "*extraordinary smooth topography with long-regular and very slight slopes*" are also extensive string, or ribbed, fens, of astonishing regularity over large areas. In this regard, they are similar to the Echoing River fens of the westernmost Ontario Lowland, similarly distant from the modern coast and also occupying extraordinarily flat, sloped terrain laid down in similar proglacial depositional environments.

Other minerotrophic wetlands along the Attawapiskat include rich riparian (ice-scour) meadow marshes, and thickets and other swamps on islands and in small tributary drainways close to the river. These also include wetlands created by beaver. Of particular interest are the near-river fluvio-karst systems on the central Attawapiskat River (90km upstream), and their associated organo-karst sinkhole systems that pock the hinterland as much as 30km southward (Cowell and Riley 1979, Cowell 1983; first termed "*cavernous limestones*" by Bell in 1887). Wetland

Minerotrophic karst limestone sinkholes in acidic peatlands south of the Attawapiskat River.

features associated with these include disappearing lakes and streams, and drawdown sinkhole wetlands that surround the bedrock entry points into the karstic limestone bioherms. The drawdown sinkholes support various marshes, meadow marshes and ephemeral wetlands, reflecting their seasonal flood and dessication cycles. Drainage of the sinkholes is into the Attawapiskat River.

HAWLEY AND AQUATUK LAKES

Described above are studies in this area that focus on the development of palsas and peat plateaus (Sjörs 1961a, Railton and Sparling 1973). These features can be treeless or with scattered *Picea mariana* up to 10% cover, often tipped or tipping, or dwarfed as *krummholz*. Both palsa initiation and palsa collapse can occur at the same time in different sites, as can be seen by the close proximity of collapse pools inside treed peat plateaus and newly rising mounds not yet of palsa dimensions. Peat filled basins often have marginal spruce zones while their deeper-peat interiors are occupied by raised, lichen-covered, permafrost palsas intersected by interstitial drainways and bog pools. Open bog is infrequent in the area, although unfrozen open bog vegetation can occur. Treed lowshrub bog is the most frequent bog type.

The Sutton Ridge upland and the terrain on the flanks around it are anomalous in the Lowland, with more contained "*basin*" wetlands than elsewhere, including, for example, scattered lakes. The lakes support mineral wetlands, with their shallow and deep waters dominated by aquatics like *Potamogeton* spp., *Ranunculus aquatilis* s.l., *Utricularia vulgaris* and *Sparganium fluctuans*. Minerotrophic wetlands are more frequent than ombrotrophic peatlands. High-pH fens with shallow peats over calcareous till are frequent (pH 7.1-8.3), often with highly diverse floristic assemblages. These fens can be the hollow phase of patterns dominated by treed bog hummocks. Other fens are patterned with *Sphagnum fuscum* rib separators, even though they are calcareous groundwater fens. Whether in fens or bogs, the raised bog islands that are common southward no longer occur, and their equivalent on the landscape are frozen, bog-like palsas and peat plateaus, with interstitial bog hollows among them that are variable in wetness and in composition.

TOP. The heights of the Sutton Ridges near Aquatuk, stand in striking contrast to the surrounding Lowland.

BOTTOM. Raised peat plateau with eroding sides, Aquatuk area.

SHAGAMU

Typical of the maritime tundra along the Ontario Hudson Bay coast, the terrain surrounding the Shagamu River mouth is congested with dense swarms of parallel raised beachridges, terracing a coastal gradient that is steeper than anywhere on James Bay. The inter-ridge depressions are small, diverse wetlands. The lowest intertidal marshes are brackish clay flats where *Puccinellia phryganodes, Potentilla anserina* var. *groenlandica, Stellaria humifusa, Plantago maritima* and *Ranunculus cymbalaria* are predictable. Above these, in some places in a shifting gradient but in most places separated by beachridges, are supratidal meadow marshes dominated by *Festuca rubra, Carex subspathacea, C. glareosa, C. mackenziei, Dupontia fisheri* and *Arctophila fulva*, and also including most of the intertidal dominants at significant vestigial cover values. These proteinaceous meadows are grazed voraciously by waterfowl (Jefferies *et al.* 2006).

TOP LEFT. Tidal marshes and meadow marsh dominate the coastward inter-ridges swales.

TOP RIGHT. Beachridges and inter-ridge wetlands all permafrost, mouth of Shagamu River

RIGHT. Species-rich tundra heath often has >30cm of frozen peat, Shagamu (*Rhododendron lapponicum, Salix reticulata*).

Inland, the next inter-ridge wetlands often include open water ponds bounded by supratidal and freshwater marsh. These breeding, moulting and flight ponds range from freshwater to brackish, and are variable in pH (7.7-(8.5)-9.4), salinity (0-(0.5)-1.6%) and conductivity (490-(1100)-2570µmhos)(n=7). More saline ponds are also documented (Sims *et al.* 1987). Dominants include many species: *Myriophyllum sibiricum, Ranunculus aquatilis, R. hyperboreus, R. gmelinii, Carex aquatilis, Hippuris vulgaris, Potamogeton pusillus, P. pectinatus, P. filiformis, Zannichellia palustris, Callitriche hermaphroditica*. (Similar sites are reported at the Pen Islands by Kershaw (1974), spread out there on the shallowest of gradients on the northwest coast.)

The inter-ridge ponds become less frequent away from the coast, as they fill with peat and shift to freshwater marsh, lowshrub meadows, and permafrost fens and bogs (plateaus and nets). Lowshrub thickets and meadows dominate the sheltered grades rising on to the beachridges, and these become rich in moss and lichen species, even more so than open meadows. Rising even higher, as exposure increases, the low shrubs shift to a more dwarf physiognomy and to arctic species of dwarf stature, grading into mossy wet tundra heath on the upper slopes and the exposed edges of ridges (Sims *et al.* 1987).

This maritime tundra is distinctive arctic vegetation, and elements of it often meet the peat-depth criterion for a peatland and often share floristic similarities with peatlands (Maycock 1974, Kershaw 1974). Ice is usually present in it, usually more prevalent than water in the summer, and it enjoys a positive overall water balance because of the fog zone along Hudson Bay, which strongly reduces summer sunshine and evapotranspiration. As a result, peaty turf accumulates. Tundra is not used here to describe a distinct wetland formation, but is noteworthy nonetheless because tundra and tundra peatlands grade into each other directly.

Tundra's place on the landscape is on beachridges or on their mossy margins, in areas of alluvial or lacustrine silts and in shallow peats. Tundra is a diverse association of prostrate arctic shrubs and diminutive arctic herb, grass and sedge species. Where there is moisture, it can be dominated by a matrix of mosses, such as on the slopes of beachridges and in moist areas at the bases of ridges, perhaps reflecting the distribution of late-spring snow beds. On the drier tops of beachridges, even where more than 5 to 10cm of peat have accumulated, lichens often dominate. Usually, the bright boreal lichens such as *Cladina alpestris*, *C. rangiferina* and *C. mitis* are not dominant, their place taken by greyer and more species-diverse lichen assemblages. On riparian levees and areas where silt is deposited annually, the prostrate shrubs themselves dominate, without strong moss or lichen cover. It is in this riparian tundra heath, often with shallow peats, that polygons or polygonal patterns of ice wedges occur. Ice-wedge polygons appear less frequently in areas where marine silts and clays, and deep peats, mantle the landscape.



Ecoregional Wetland Characteristics

Based on Riley (1982) and Mortsch (1990); in order of ecoregion (Crins *et al.* 2009) and wetland region (NWWG 1988).

Parnassia palustris, *Pedicularis groenlandica*, *Festuca rubra*, Hudson Bay Lowland.

Meadow marsh, *Cicuta mackenzieana*, Shagamu rivermouth, Hudson Bay.

Within the Hudson Bay Lowland ecozone there are distinct ecoregions of land and water that have characteristic ranges and patterns of climatic variables like temperature, precipitation and humidity, that are reflected in vegetation types, peat formation and other ecological processes, and associated biota. The Hudson Bay Lowland ecozone represents a globally anomalous landscape in that a higher proportion of the ecozone is dominated by wetlands than any other in North America, and its constituent ecoregions have characteristic wetland types, patterns and frequencies as a result (Zoltai 1979, Crins *et al.* 2009).

ECOREGION 0E, Coastal Hudson Bay Lowland

(Humid high subarctic (SHh) wetland region)

National SHh Wetland Characteristics: Broad areas of polygonal peat plateau, horizontal (immature and/or unpatterned) fen, shore fen and inter-ridge fen. Initial stages of peat accumulation and palsa development are typical of immature fens, with deeper peats maturing to peat plateau. Salt marsh and coastal meadow marsh are common. A region of more or less continuous permafrost, with discontinuous permafrost southward.

A broad, exposed maritime zone of more or less continuous permafrost, which extends its influence into all wetland types as well as into coastal terrestrial sites such as tundra-heath beachridges and river levees. Lichen-dominated PEAT PLATEAU and TREED BOG dominate. SHRUB MEADOW MARSH and THICKET SWAMP are frequent at coastal and tundra sites. The relative extent of INTERTIDAL/ SUPRATIDAL wetlands is less than along James Bay because of the steeper gradients. The coast's expansive displays of parallel beachridges, often extending far inland, support a great variety of inter-ridge MEADOW MARSH and MARSH types, grading into FEN systems towards the interior, and then developing into palsas and coalesced palsa fields (PEAT PLATEAU). PEAT PLATEAU also grades into uniformly raised, unpatterned, permafrost (tundra) FEN and BOG plains of considerable extent south and west of Cape Henrietta Maria, southeast of the Pen Islands, and between the Winisk and lower Severn Rivers. There are large PEAT PLATEAU areas, such as in the latter area, where thermokarst lake systems erode downwind as shallow lakes and ponds, with distinct zones of peat deposition upwind. Ice-wedge polygon patterns occur in a range of shallow-peat wetland types. Raised and youthful coastal features, as yet unpaludified, support terrestrial vegetation. The breadth of tidal wetlands is greatest in the estuaries of rivers and around off-shore islands, such as around the Pen Islands.

ECOREGION 1E, Hudson Bay Lowland

(Low subarctic (SL) wetland region)

National SL Wetland Characteristics: Common wetlands are peat plateau to the north, and patterned or unpatterned fen, the latter generally without permafrost southward. Peat substrates are deeper than in areas northward. An area of transitional permafrost discontinuity. Southward, peat plateau shifts to patterned bog.

Characterized by a shallow topographic decline from the Shield northward to the east-west 'shoulder' that lies across the lowland (the Sutton Ridge uplands and associated till uplands, and the till uplands west of the Severn River). These areas support upland lichen woodland (much burned over in the west) as important landscape elements. These uplands are younger, and have shallower peat accumulations and more sloping terrain; OPEN FEN is characteristic of these areas, as well as the region as a whole. In the

coastward half of the ecoregion, PEAT PLATEAU and other permafrost-related features dominate, and extend into FEN systems. The coastal and estuarine systems on James Bay are considerably narrower north of Akimiski Island and occupy a smaller proportion of overall wetland types than on the coast to the south. A drier climatic regime in the western half of the ecoregion results in a higher proportion of fire-dependent and/or fire-related landscape features; LICHEN-RICH BOG and PEAT PLATEAU in which fire plays a role are widespread to the west, particularly along alluvia-related riparian PEAT PLATEAU. Major drainage channels created by the draining postglacial Lake Agassiz contain major sloping FEN systems in the west.

ECOREGION 2E, James Bay Lowland

(Humid high boreal (BHh) and mid-boreal (BMh) wetland region)

Northern Portion (ecodistrict 2E-1)

National BHh Wetland Characteristics: Open patterned bog, and ribbed and netted fen. Wooded peat plateau and palsa fields occur northward, with evident collapse features and initiation phases.

Dominated by patterned OPEN BOG (deeper peats) and FEN systems (shallower peats), reflecting the gentle topographic rise from the James Bay coast, and a strong correlation of peat depth, elevation and distance-from-coast. This correlation is expressed below about 65m ASL as relatively unpatterned and immature coastal OPEN and TREED FEN. The overall densities of trees in these systems are much lower than in similar subformations southward, such as in the Moose River basin. On higher terrain, in deeper peats, TREED and OPEN BOG dominates, and there is a high incidence of permafrost, expressed northward as PEAT PLATEAU, but more frequent southward as incipient palsa features (TREED and OPEN) and under raised TREED BOG islands in OPEN FEN and BOG systems (and with associated collapse features). A secondary element of provincial significance are limestone karst wetlands, with exaggerated seasonal variation of depth-to-water, occurring both south and north of the Attawapiskat River. Coastal and estuarine wetlands are similar in scope and proportions to those to the south. Broad unpatterned OPEN and TREED FEN closer to James Bay grades coastward into immature coastal FEN and inter-ridge SUPRATIDAL/INTERTIDAL MARSH and MEADOW MARSH.

Southern Portion (ecodistricts 2E-2,4)

National BMh Wetland Characteristics: Broad expanses of deep treed bog and fen, with sparse occurrence of more temperate thicket, broadleaf (floodplain), and conifer (cedar) swamp. Permafrost is generally absent and peat is often deeper than 4m. Sporadic permafrost occurs under raised bogs islands and fen/bog pools. Evidence of fen ('poor' fen) transitioning to bog is widespread. Black spruce swamp is common. Inland marsh is common, while coastal meadow marsh and thicket are similar to areas northward.

These southernmost wetlands support more temperate elements than elsewhere in the Lowland, such as DECIDUOUS SWAMP and white cedar FEN and SWAMP, especially in its warmer interior. There remain some permafrost-related wetlands, such as under raised TREED BOG islands and FEN/BOG POOLS, where predictable discontinuous permafrost reaches its southern limits. The Moose River basin has well-drained, level slopes over broad expanses (draining off the Kinoje till moraine between the Albany and Moose watersheds) and these support the largest homogenous TREED FEN expanses, which grade into TREED BOG and CONIFER SWAMP along streams, and into forest along river levees. The Albany River basin is characterized by large patterned OPEN BOG and, to a lesser extent, OPEN FEN, with peat depths over 4m in interior areas south of 50°30'N and west of 83°W. Interior OPEN BOG is more seasonally droughty than elsewhere in the Lowland, supporting denser graminoid cover (especially sedge and cotton grass) than elsewhere (see photo page 20). Close to the Shield 'escarpment' are smaller wetlands perched between bedrock-controlled rises, especially in the east where the topographic rise is relatively steep. The same moraine between the Albany and Moose rises into a till plateau between the Kenogami and Missinaibi Rivers, with less wetland cover than in lower elevations on its flanks (Pala and Wischet 1982).

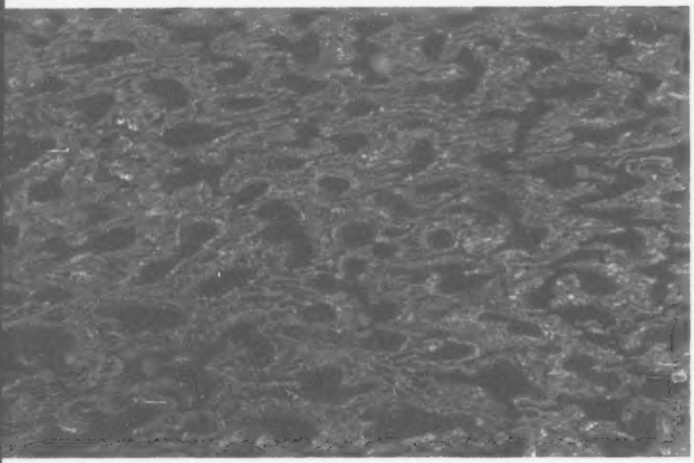
The widest Lowland expanses of coastal and estuarine wetlands occur along the southwest and southern James Bay coast, with broad and productive INTERTIDAL/SUPRATIDAL areas as much as 10km wide in many places. MARSH, MEADOW MARSH, THICKET SWAMP and LOWSHRUB MEADOW MARSH are common, often extending inland for considerable distances, especially in the estuaries of major rivers. (At the southern transition to the adjacent Shield, especially away from the upland Pinnard Moraine, SWAMP and TREED BOG dominate many areas, transitional to the Abitibi Plains ecoregion (3E) to the south.

Major Wetland Types

Peat Plateau, Open and Treed
Treed Bog
Open Shrub Bog
Open Graminoid and Sphagnum Bog
Bog Pool and Fen Pool
Treed Fen
Open Shrub Fen
Open Graminoid Fen
Swamp, Conifer and Broadleaf
Thicket Swamp
Marsh and Meadow Marsh, Freshwater
Marsh and Meadow Marsh, Coastal
Marsh and Meadow Marsh, Estuarine
Water, Shallow and Deep

See Appendices for additional detail.

Peatland terrain in the northcentral interior overlaying a former terrain of beachridges and inter-ridge swales.



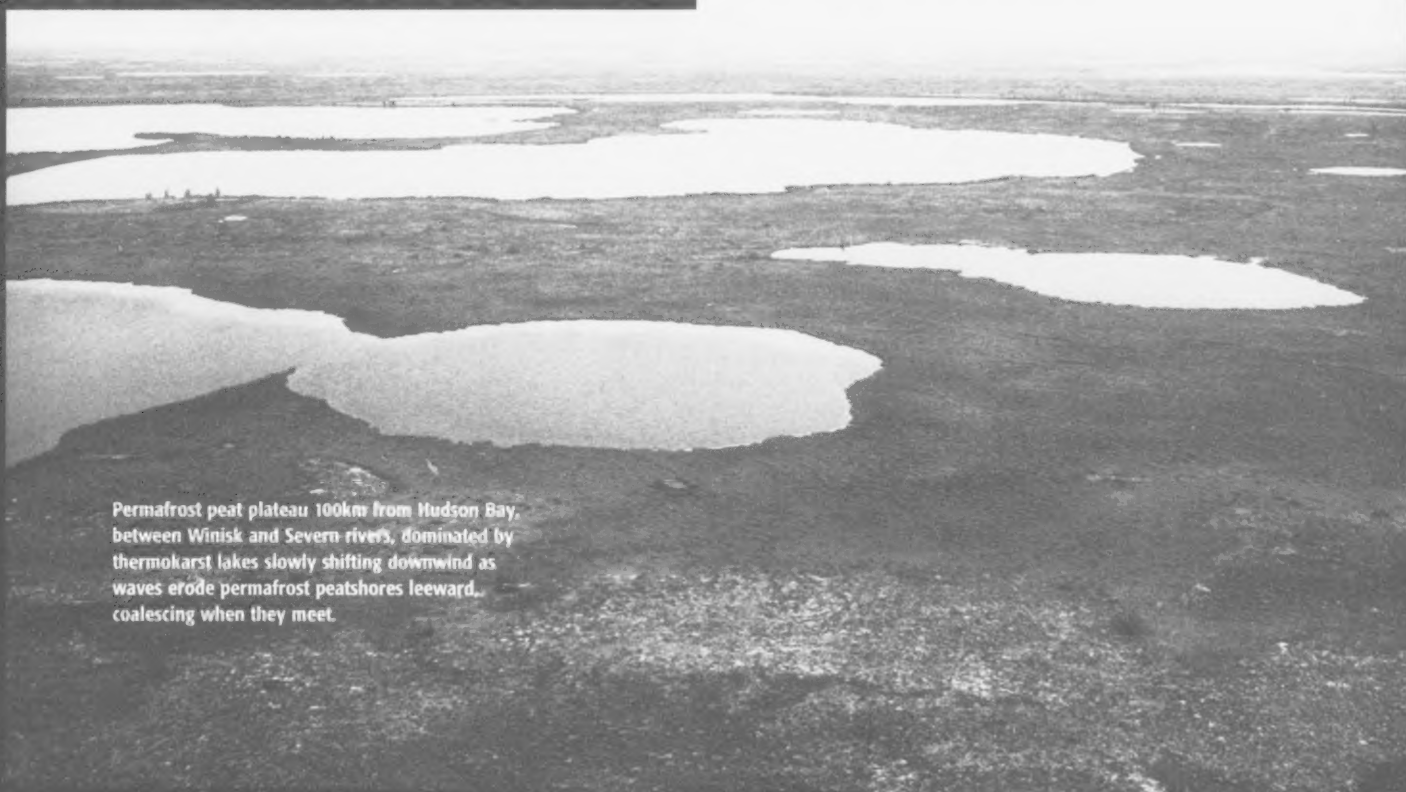
Peat Plateau, Open and Treed

Ecoregions 0E, 1E. Average peat depth >3.5m (n=3). Continuous permafrost, with active layer averaging 36cm (n=4). (Data deficient due to difficulty penetrating permafrost-peat to substrates.)

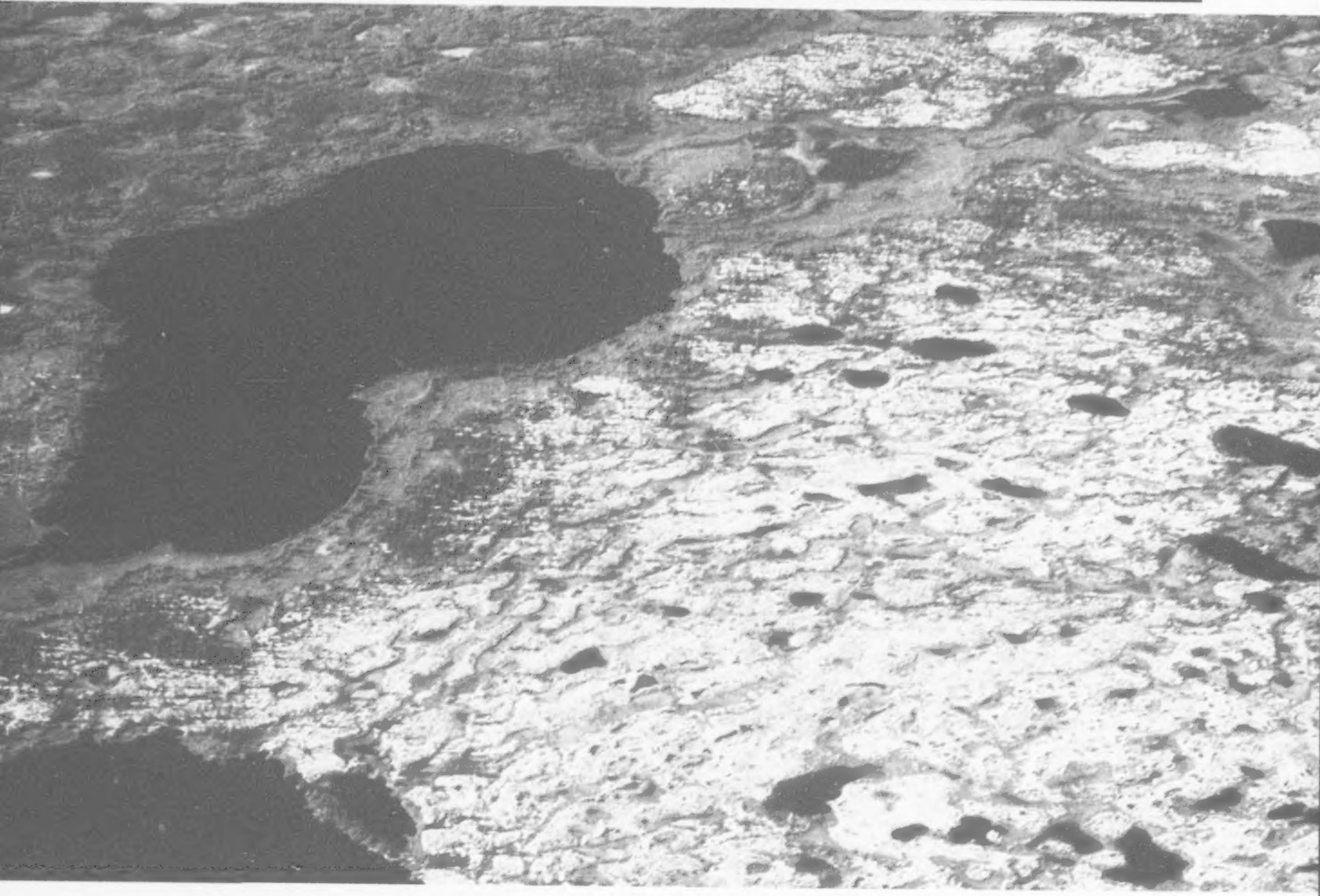
Common Physiognomic Groups and Dominance Types	Ecoregion	Permafrost
TREED LICHEN-RICH LOWSHRUB PEAT PLATEAU		
Picea mariana - Ledum groenlandicum - Cladina	1E	c
TREED LOWSHRUB PEAT PLATEAU		
Picea mariana - Ledum groenlandicum	1E	c
OPEN LICHEN-RICH LOWSHRUB PEAT PLATEAU		
Ledum - Cladina	0E, 1E	c
Rhododendron lapponicum - Ledum decumbens - Cladina	1E	c
OPEN LOW SHRUB PEAT PLATEAU		
Chamaedaphne calyculata - Cladina	0E	c

LEFT TOP. Net bog, in the northwest Lowland, composed of open graminoid bog (15%), bog pools (40%) and treed and open permafrost peat plateau islands and ribs, which separate the pools and terrace the wetland (35%).

LEFT. Eroding edges, mature palsa, Aquatuk Lake.



Permafrost peat plateau 100km from Hudson Bay, between Winisk and Severn rivers, dominated by thermokarst lakes slowly shifting downwind as waves erode permafrost peatshores leeward, coalescing when they meet.



TOP LEFT. Fens and lichen-rich palsa ridges, between beachridges, 10km from Hudson Bay, Shell Brook.

TOP RIGHT. Peat plateau drill site; permafrost 3.4m over frozen clay, 70km from Hudson Bay up Pipowitan Creek.

ABOVE. Permafrost peat plateau; lichen-rich in right foreground and recovering from fire in left background.

Treed Bog

Ecoregions 1E, 2E. Average peat depth 1.5m in ecoregion 1E (n=6); >2.1m ecoregion 2E (n=18). Ecoregion 1E sites with discontinuous permafrost (ice lenses) (n=4) have average active layers 35cm.

Common Physiognomic Groups and Dominance Types	Ecoregion	Permafrost
TREED SHRUB-RICH BOG		
Picea mariana - Chamaedaphne calyculata	2E	d, n
Picea mariana - Kalmia angustifolia	2E	d, n
TREED LOWSHRUB BOG		
Picea mariana	1E, 2E	n
Picea mariana - Chamaedaphne calyculata	1E, 2E	n
Picea mariana - Ledum groenlandicum	2E	n, d
TREED LICHEN-RICH LOWSHRUB BOG		
Picea mariana - Cladina	1E, 2E	n
TREED GRAMINOID BOG		
Picea mariana - Carex oligosperma	2E	n

ABOVE. Raised treed bog often frames, terraces and edges bog pool complexes in the southwest interior.

Treed lichen-rich bog. Groundfire has burned off the lichen, leaving the *Sphagnum*; Kinoje area.

RIGHT. Tear-shaped treed bog islands show water-flow direction in fen complex; southwest interior Lowland.

TOP. Southern interior plateau bog, comprised of open lichen-rich lowshrub bog (70%), bog lakes and pools (20%) and black spruce bog and swamp margins (10%).

BOTTOM. A. Boissonneau; R. Mussakowski, S. Pala, 1979 fieldcrew; open lowshrub bog in southern interior.

Open Shrub Bog

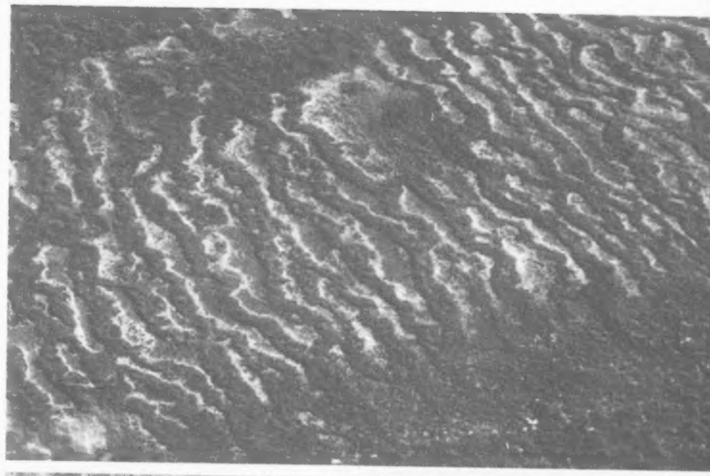
Ecoregions 0E, 1E, 2E. Average peat depth >1.8m in ecoregions 0E, 1E (n =11); >2.6m in ecoregion 2E (n =52). Includes sites with continuous permafrost, with discontinuous permafrost (ice lenses), or without any summer ice.

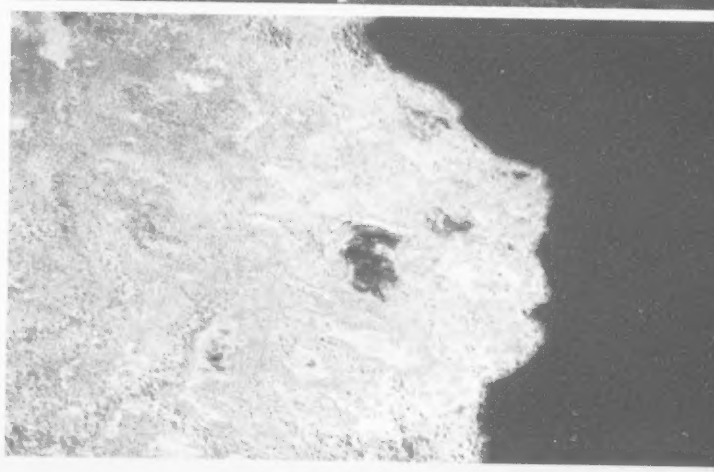
Common Physiognomic Groups and Dominance Types	**Ecoregion**	**Permafrost**
OPEN SHRUB-RICH BOG		
Picea mariana (shrub) - *Thuja occidentalis* (shrub)	2E	n
OPEN LOWSHRUB BOG		
Chamaedaphne calyculata	0E, 1E, 2E	c, n
Chamaedaphne calyculata - Graminoids	2E	c, n
OPEN LICHEN-RICH LOWSHRUB BOG		
Chamaedaphne calyculata - *Cladina*	0E ,1E, 2E	d, n
Ledum groenlandicum - *Cladina*	2E	d

Open Graminoid and Sphagnum Bog

Ecoregions 0E, 1E, 2E. Average peat depth >1.9m in ecoregions 0E, 1E (n=16); >2.7m in ecoregion 2E (n=54). Includes sites with continuous permafrost, with discontinuous permafrost (ice lenses), or without any summer ice.

Common Physiognomic Groups and Dominance Types	**Ecoregion**	**Permafrost**
OPEN GRAMINOID BOG		
Carex aquatilis	0	c, n
Carex limosa	0, 2E	c, n
Carex magellanica	1, 2E	n
Carex oligosperma	1, 2E	n
Carex rariflora	0	c
Eriophorum vaginatum	1, 2E	c, n
Rhynchospora alba	2E	n
Scheuchzeria palustria	1, 2E	n
Scirpus cespitosus	0, 1, 2E	c, n
OPEN SPHAGNUM BOG		
Sphagnum fuscum	2E	d,n
Sphagnum magellanicum	2E	d
Sphagnum nemoreum	2E	n

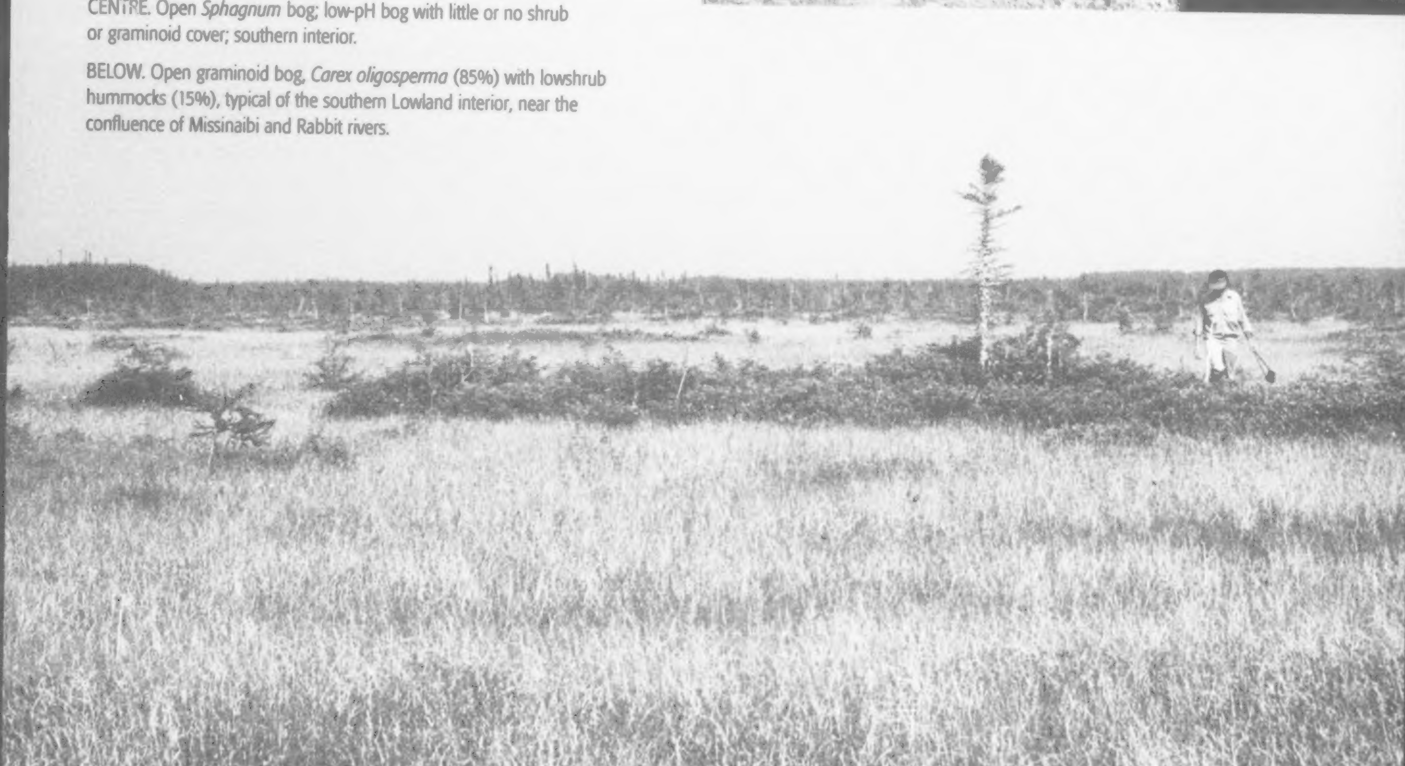


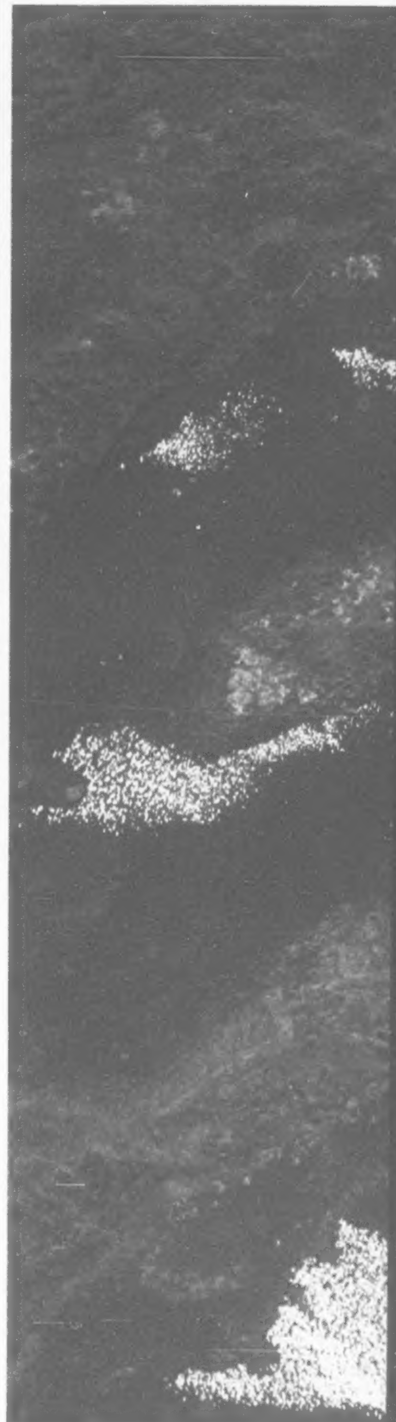


TOP. Ladder bog; graminoid bog lows terraced by lowshrub bog ribs; southern interior Lowland.

CENTRE. Open *Sphagnum* bog; low-pH bog with little or no shrub or graminoid cover; southern interior.

BELOW. Open graminoid bog, *Carex oligosperma* (85%) with lowshrub hummocks (15%), typical of the southern Lowland interior, near the confluence of Missinaibi and Rabbit rivers.





Bog Pool and Fen Pool

Open bog pools frequent in ecoregion 2E. Average peat depth >2.8m (n=5); with discontinuous permafrost (ice lenses) or without summer ice. Open fen pools frequent in ecoregions 0E, 1E, 2E. Average peat depth >2.8m (n=13); includes sites with continuous permafrost, or discontinuous permafrost (ice lenses), or no summer ice.

Common Physiognomic Groups and Dominance Types	**Ecoregion**	**Permafrost**
OPEN POOL BOG		
Cladopodiella fluitans	2E	d, n
Sphagnum magellanicum - Carex oligosperma	2E	n
Sphagnum lindbergii	1E	n
Sphagnum majus	1E, 2E	n
OPEN POOL FEN		
Eriophorum chamissonis	0E	d
Carex limosa	0E, 1E ,2E	c, n
Menyanthes trifoliata	2E	d, n
Rhynchospora alba	2E	n
Scorpodium scorpioides	2E	d, n

TOP LEFT. Net fen 27km inland from Hudson Bay, west of the Winisk River, composed of open graminoid fen (50%), fen pools (35%) and treed permafrost peat plateau islands and ribs separating and terracing the wetland (15%).

BOTTOM LEFT. Lime-rich marl fen pools fed by groundwater flowing out of ridges, south Albany River basin, Carling Lake area.

TOP. Treed lowshrub fen as raised, parallel ribs in extensive fen; northcentral interior.

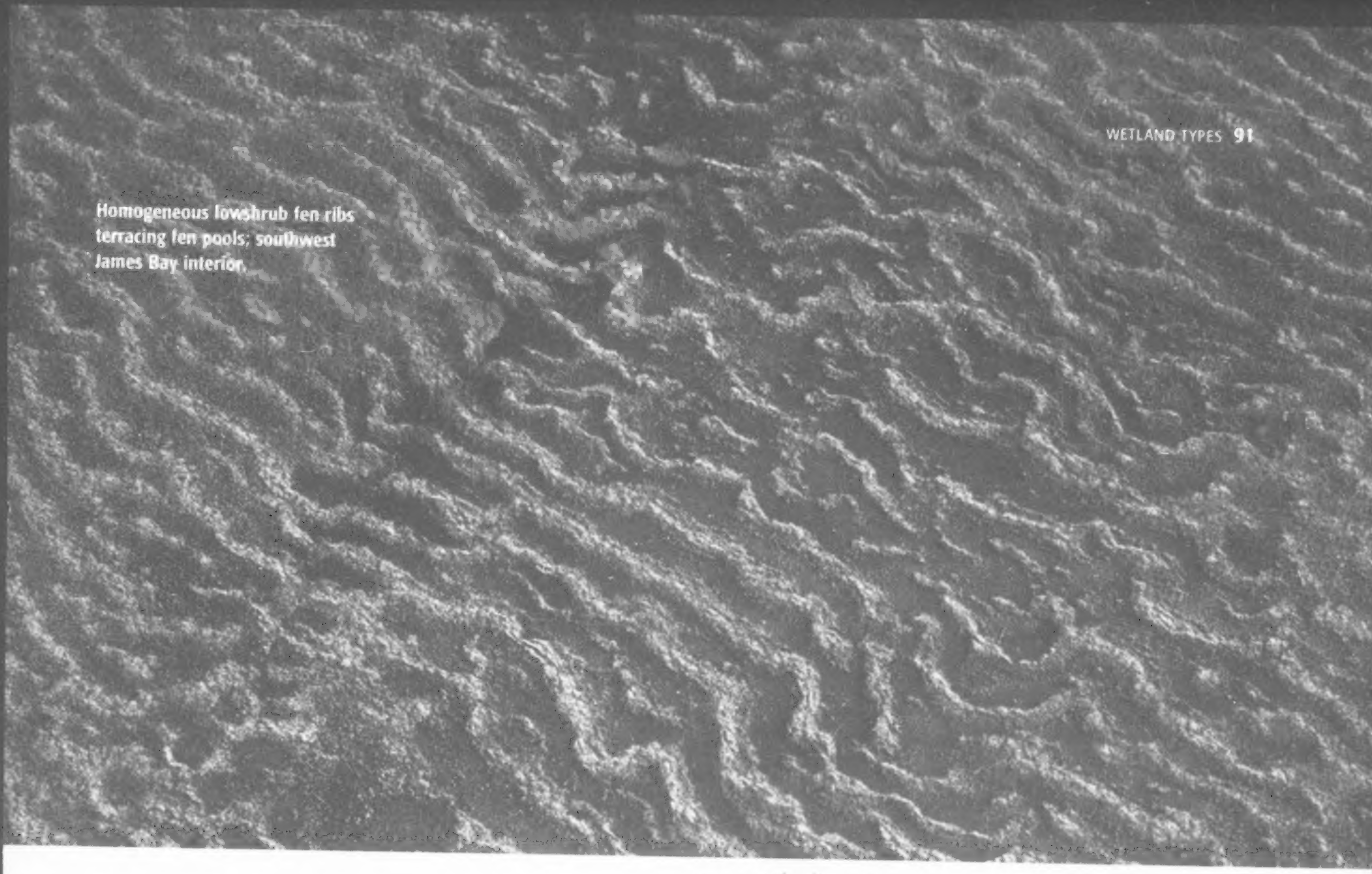
ABOVE. Tamarack fen dominates the flat gentle slopes of the Moose River basin, here a treed graminoid fen.

Treed Fen

Ecoregions 0E, 1E, 2E. Average peat depth 2.1m in ecoregions 0E, 1E (n=6); 2.3m in ecoregion 2E (n=19). No permafrost noted (n=25).

Common Physiognomic Groups and Dominance Types	**Ecoregion**	**Permafrost**
TREED SHRUB-RICH FEN		
Larix laricina - Betula pumila	0E, 2E	n
Larix laricina - Betula pumila - Chamaedaphne calyculata	1E, 2E	n
TREED LOWSHRUB FEN		
Larix laricina - Andromeda glaucophylla	2E	n
Larix laricina - Betula pumila	0E, 1E, 2E	n
Larix laricina - Salix candida	0E	n
Thuja occidentalis - Larix laricina - Betula pumila	2E	n
Thuja occidentalis - Myrica gale	2E	n
TREED GRAMINOID FEN		
Larix laricina - Carex chordorrhiza - Carex limosa	2E	n
Larix laricina - Carex lasiocarpa	2E	n
Larix laricina - Carex limosa - Scirpus hudsonianus	1E, 2E	n
Thuja occidentalis - Scirpus hudsonianus - Scirpus cespitosus	2E	n

The extent and homogeneity of the treed fens in the Moose River basin is unique in Canada.



Homogeneous lowshrub fen ribs terracing fen pools; southwest James Bay interior.

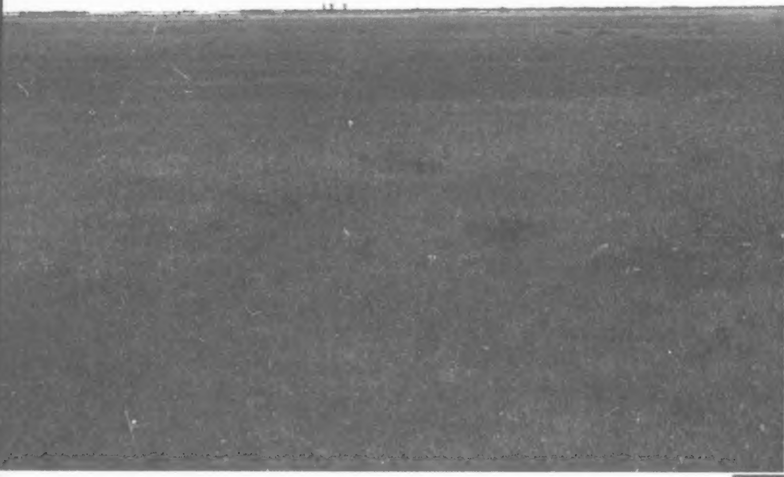
Open Shrub Fen

Ecoregions 0E, 1E, 2E. Average peat depth 1.4m in ecoregions 0E, 1E (n=3); no summer ice, or with continuous permafrost (active layer 35cm). Average peat depth >1.6m in ecoregion 2E (n=11); no permafrost noted.

Common Physiognomic Groups and Dominance Types	Ecoregion	Permafrost
OPEN SHRUB-RICH FEN		
Larix laricina (shrub) - *Betula pumila*	1E	n
Salix pedicellaris	1E	n
OPEN LOWSHRUB FEN		
Andromeda glaucophylla	2E	n
Betula pumila	0E, 2E	n
Chamaedaphne calyculata	2E	n
Larix laricina (shrub) - *Betula pumila*	0E	c, n
Myrica gale	2E	n
Potentilla fruticosa	2E	n
OPEN DWARF-SHRUB FEN		
Arctostaphylos alpina	0E	c
Vaccinium uliginosum	0E	c

RIGHT TOP. Open lowshrub fen, *Potentilla fruticosa*, Kinoje Lake area.

RIGHT. Fen drain near Kinoje, south of Albany. Lowshrub fen ribs separate fen pools, surround bog islands.



Open Graminoid Fen

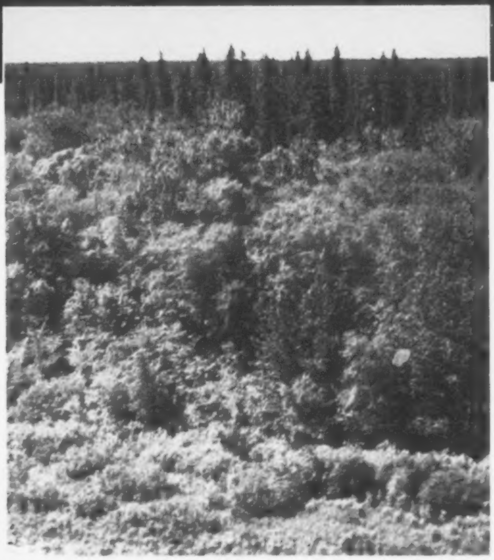
Ecoregions 0E, 1E ,2E. Av. peat depth >1.3m in ecoregions 0E ,1E (n=28); with no summer ice or with continuous permafrost (active layer av. 51cm, n=15). Average peat depth >1.8m in ecoregion 2E (n=33); no permafrost noted.

Common Physiognomic Groups and Dominance Types	**Ecoregion**	**Permafrost**
OPEN GRAMINOID FEN		
Carex aquatilis	0E	c, n
Carex chordorrhiza	0E, 1E, 2E	c, n
Carex exilis	2E	n
Carex lasiocarpa	2E	n
Carex limosa	0E, 1E, 2E	c, n
Carex livida	0E, 1E	n
Carex saxatilis	0E	c
Carex utriculata	2E	n
Scirpus cespitosus	0E, 1E, 2E	c, n
Scirpus hudsonianus	1E	n

ABOVE. Open graminoid permafrost fen, *Scorpidium turgescens-Carex aquatilis*; Cape Henrietta Maria area.

RIGHT. Largest string fens in the Lowland, 240km from the coast on the Ontario-Manitoba border. Raised linear ribs of shrub fen run perpendicular to water flow, terracing a long flat gradient of graminoid fens and pools.

INSET. Open permafrost fen, with incipient ribbing and peat plateau islands; 13km ESE of Fort Severn.



TOP. Beachridge conifer forest grading into backridge conifer swamp; central James Bay coast.

ABOVE. Broadleaf elm swamp, Kenogami River.

Swamp, Conifer and Broadleaf

Ecoregions 1E, 2E. Average peat depth 0.8m in ecoregion 1E (n=2); no summer ice noted. Average peat depth 1.3m in ecoregion 2E (n=5); no permafrost noted or discontinuous, with ice lenses at average 43cm (n=2).

Common Physiognomic Groups and Dominance Types	Ecoregion	Permafrost
CONIFER SWAMP		
Larix laricina	2E	n
Picea mariana - Ledum groenlandicum	1E, 2E	d, n
Picea glauca - Abies balsamea	2E	d
Thuja occidentalis	2E	n
BROADLEAF SWAMP		
Populus balsamifera	1E, 2E	n
Ulmus americana - Fraxinus nigra	2E	n

White spruce swamp (left), poplar swamp (right), behind riparian thickets; Attawapiskat rivermouth.

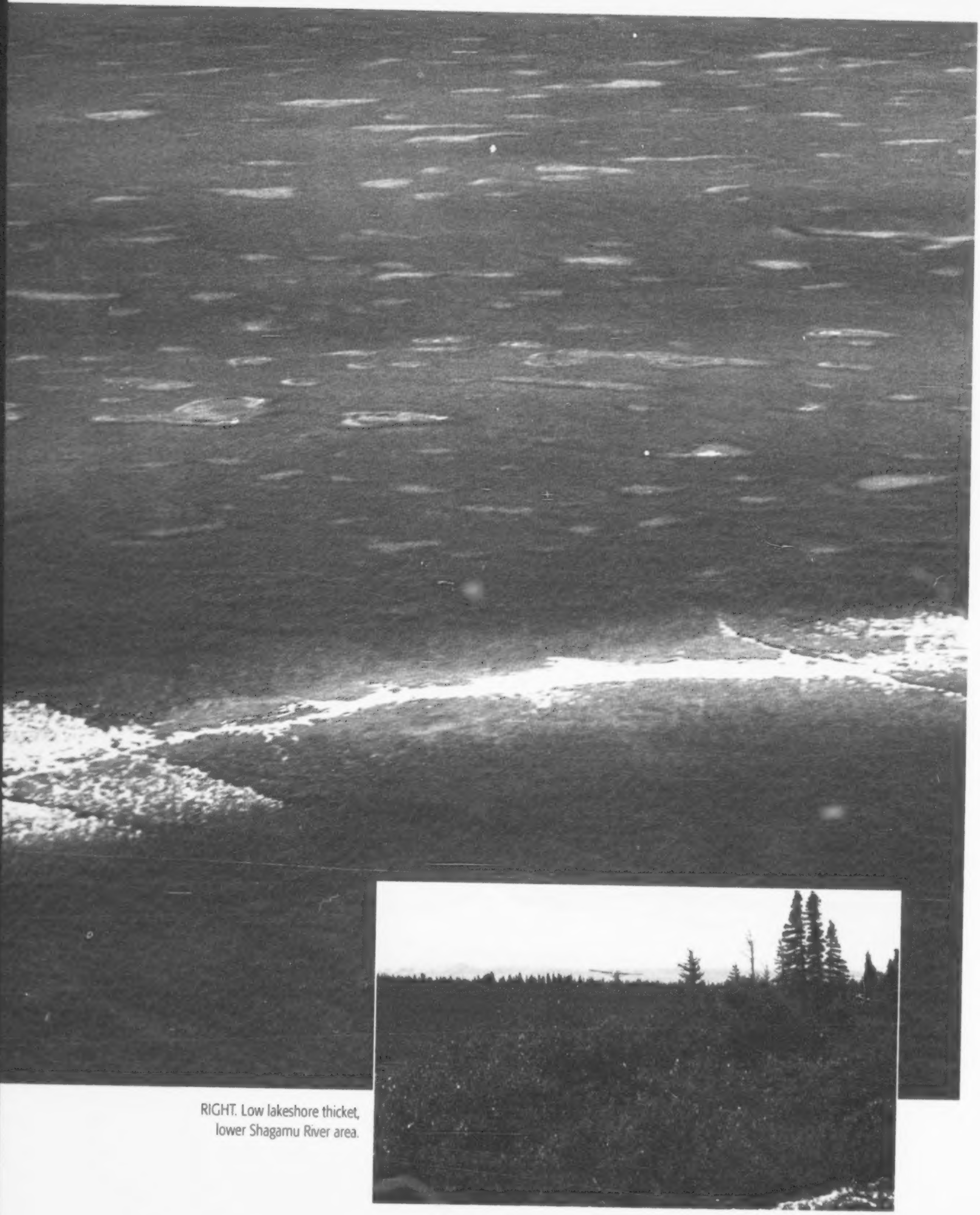
Thicket Swamp

Ecoregions 0E ,1E, 2E. Average peat depths minor and/or unmeasured; summer ice noted in ecoregions 0E and 1E, with active layers 30cm.

Common Physiognomic Groups and Dominance Types	**Ecoregion**	**Permafrost**
THICKET SWAMP		
Alnus crispa	1E	n
Alnus rugosa	1E, 2E	c, n
Cornus stolonifera	2E	n
Myrica gale	2E	n
Salix cordata	2E	n
Salix exigua	2E	n
Salix glauca	2E	n
Salix pellita	1E, 2E	n
Salix planifolia	0E, 2E	n
Salix serissima	2E	n

Low supratidal *Salix* thicket, Shagamu River.

Riparian thicket, shrub-rich meadow marsh and shallow marsh, as the result of beaver damming, here near Cape Henrietta Maria. (Note open peat plateau in background, pocked with collapse scars.)



RIGHT. Low lakeshore thicket, lower Shagamu River area.

Marsh and Meadow Marsh, Freshwater

Ecoregions 0E, 1E, 2E. Av. peat depth minor and/or unmeasured, but also up to an av. of 0.8m in ecoregions 0E, 1E (n=7) and 1.3m in ecoregion 2E (n=5). Summer ice noted in ecoregions 0E and 1E; active layers av. 28cm (n=5).

TOP. Meadow marsh typical of the flooded, ice-scoured banks of Lowland rivers; lower Shagamu River.

BOTTOM. Meadow marsh on lower Shagamu; lowshrub permafrost peat on left, and mineral meadow on right.

Common Physiognomic Groups and Dominance Types	**Ecoregion**	**Permafrost**
SHALLOW MARSH		
Arctophila fulva	0E	c
Carex aquatilis	0E	c
Carex lasiocarpa	1E	n
Carex limosa	2E	n
Carex recta	2E	n
Carex retrorsa	2E	n
Carex utriculata	0E, 1E, 2E	n, d
Eleocharis smallii	1E, 2E	n
Equisetum fluviatile	0E	c
Hipuris vulgaris	0E, 1	c, n
Menyanthes trifoliata	0E, 2E	c, n
Petasites sagittatus	0E	c
Phragmites australis	2E	n
Potentilla palustris	2E	n
DEEP MARSH		
Scirpus acutus	2E	n
Typha latifolia	2E	n
MEADOW MARSH		
Alopecurus aequalis	2E	n
Calamagrostis canadensis	2E	n
Calamagrostis stricta	0E	c
Carex aquatilis	0E, 1E, 2E	c, d, n
Carex lenticularis	2E	n
Carex saxatilis	0E, 1E	c, n
Carex viridula	2E	n
Equisetum arvense	0E	c
Equisetum variegatum	0E	c
Scirpus cyperinus	1E	n
SHRUB-RICH MEADOW MARSH		
Salix - Myrica gale - Betula pumila	2E	n
LOWSHRUB MEADOW MARSH		
Arctostaphylos rubra	0E	c
Betula pumila	0E	c
Myrica gale	0E	c
Salix brachycarpa	0E	c
Salix candida	0E, 2E	c, n
Salix glauca	0E	c
Salix pellita	2E	n
Salix planifolia	0E	c
Vaccinium uliginosum	0E	c

LEFT. *Potentilla palustris* marsh, Shagamu rivermouth area.

BELOW. The succession inland from the coast, from open water, through intertidal and supratidal marsh, to freshwater marsh, is gradual where the terraced beachridges are well separated, such as along James Bay, 27km north of the Swan River.

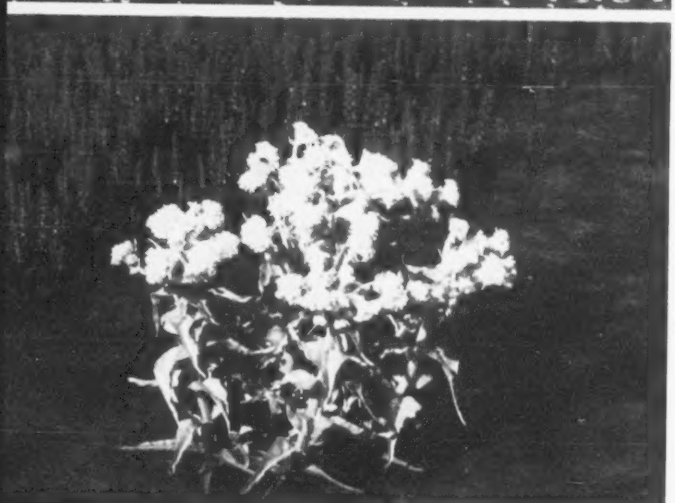
Marsh and Meadow Marsh, Coastal

Ecoregions 0E, 1E, 2E. Peat depths minor and/or unmeasured; surface waters in evaporate pools as high as pH9.0 (n=3). No observations of summer made.

Common Physiognomic Groups and Dominance Types	Ecoregion	Permafrost
SUPRATIDAL MEADOW MARSH		
Calamagrostis stricta	2E	n
Carex glareosa	0E, 2E	c, n
Carex paleacea	2E	n
Deschampsia cespitosa	2E	n
Eleocharis smallii	2E	n
Festuca rubra	0E, 2E	c, n
Hippuris vulgaris	0E, 2E	c, n
Juncus balticus	0E, 2E	n
Menyanthes trifoliata	2E	n
Myriophyllum sibiricum	0E, 2E	c, n
Petasites sagittatus	0E	n
Potamogeton filiformis	2E	n
Scirpus americanus	2E	n
Scirpus rufus	1E, 2E	n
Senecio congestus	1E, 2E	n
Zannichellia palustris	2E	n

Common Physiognomic Groups and Dominance Types	Ecoregion	Permafrost
INTERTIDAL MARSH		
Carex glareosa	0E	n
Carex mackenziei	0E, 2E	c, n
Carex paleacea	1E, 2E	n
Carex subspathacea	0E	c
Eleocharis smallii	1E, 2E	n
Hippuris tetraphylla	0E, 2E	c, n
Potamogeton filiformis - *Potamogeton pectinatus*	2E	n
Potentilla anserina var *groenlandica*	0E	c
Puccinellia phryganodes	0E, 1E, 2E	c, n
Scirpus maritimus	2E	c, n
Senecio congestus	0E, 2E	c, n
Zannichellia palustris	2E	n

BELOW. At high tide, the broad coastal marshlands along James Bay, here north of the Albany River. Magnets for feeding, breeding and migrating waterfowl and shorebirds, almost entirely Important Bird Areas.

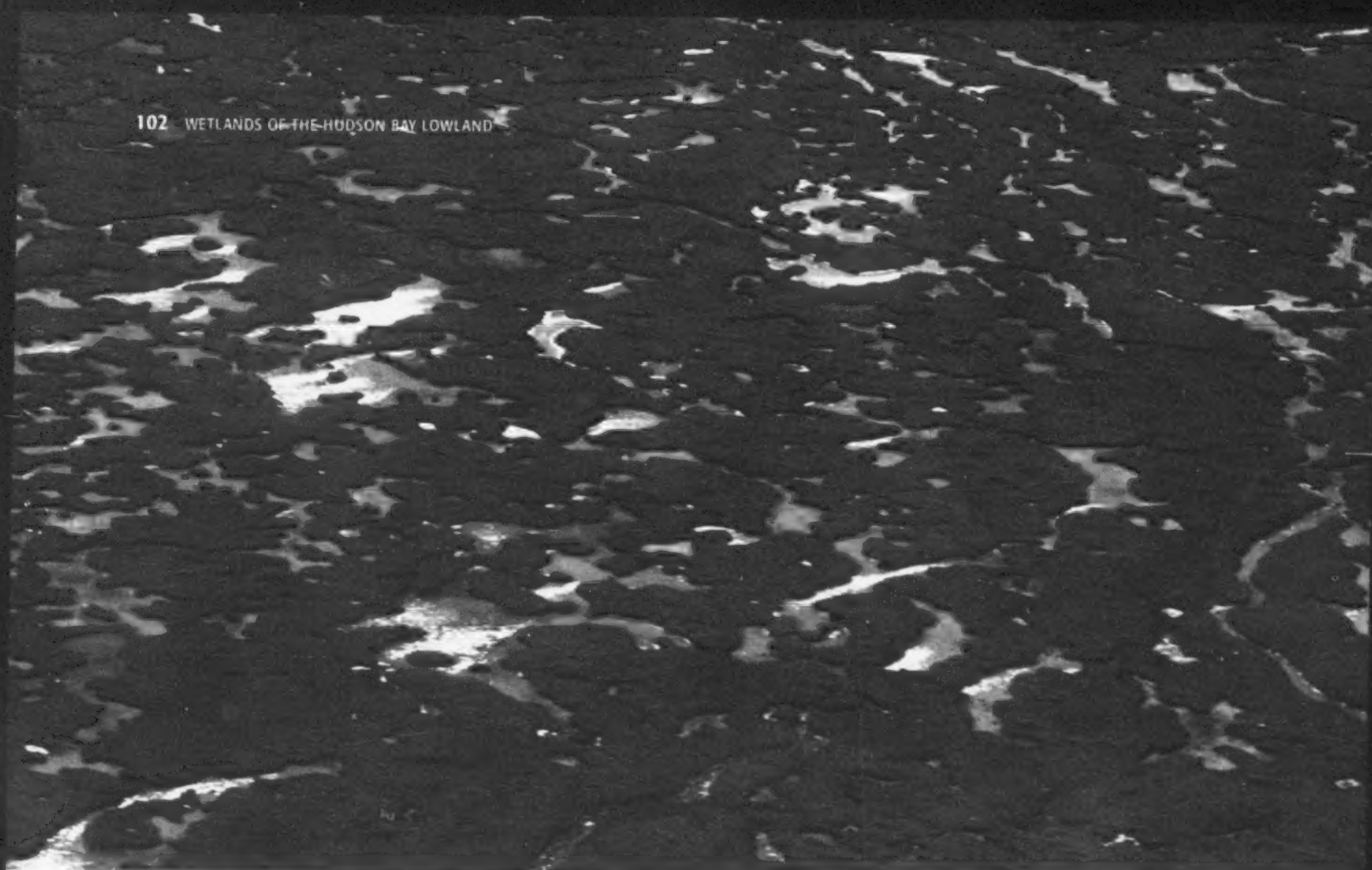


TOP. James Bay mudflats host eastern dominants like *Bidens hyperborea* (left) and westerners like *Cicuta mackenzieana,* in dynamic marshlands that colonize newly emerged land, and change with the tides, storms and ice.

CENTER LEFT. *Puccinellia phryganodes* and *Potentilla anserina* dominate intertidal marsh; lower Shagamu.

CENTER RIGHT. Low tide reveals the shifting drainage patterns of shallow pannes and swards, and drains and ribs, here in the same James Bay marshlands north of the Albany River.

BOTTOM. Marsh ragwort, *Senecio congestus*, can dominate marsh; here at Shagamu River mouth, Hudson Bay.



Marsh and Meadow Marsh, Estuarine

Ecoregions 0E, 1E, 2E. Peat depths minor and/or unmeasured; no observations of summer ice.

TOP: Dense, nutrient-rich estuarine intertidal marsh, *Senecio congestus - Eleocharis*, at the mouth of the Moose River, at Shipsands Island.

ABOVE: Intertidal estuarine marsh at Little Cape - Sutton River.

Common Physiognomic Groups and Dominance Types	Ecoregion	Permafrost
SUPRATIDAL MEADOW MARSH		
Anemone canadensis	2E	n
Agrostis gigantea	2E	n
Carex recta	2E	n
Carex limosa	2E	n
Equisetum variegatum	2E	n
Festuca rubra	2E	n
Juncus balticus	2E	n
Rhinanthus crista-galli	2E	n
INTERTIDAL MARSH		
Bidens hyperborea	2E	n
Carex paleacea	2E	n
Carex recta	2E	n
Equisetum fluviatile	2E	n
Hippuris vulgaris	2E	n
Juncus nodosus	2E	n
Lysimachia thyrsiflora	2E	n
Potentilla anserina var. *groenlandica*	2E	n
Puccinellia phryganodes	2E	n
Satittaria latifolia	2E	n
Scirpus americanus	2E	n
Scirpus validus	2E	n
Senecio congestus	2E	n

Water, Shallow and Deep

Ecoregions 0E,1E,2E. Peat depths minor and/or unmeasured; summer ice unmeasured.

Common Physiognomic Groups and Dominance Types	Ecoregion	Permafrost
SHALLOW WATER		
Menyanthes trifoliata	2E	n
Myriophyllum sibiricum	0E	c
Potamogeton alpinus	1E	n
Potamogeton filiformis	0E, 2E	c, n
Potamogeton gramineus	2E	n
Potamogeton richardsonii	0E	c
Ranunculus aquatilis (s.l.)	0E, 1E	c, n
Ranunculus gmelinii	0E	c
DEEP WATER		
Potamogeton	1E, 2E	n
Nuphar	1E, 2E	n
Zostera (coastal offshore)	1E, 2E	n

Shallow water and marsh, around limestone karst sinkhole lake south of central Attawapiskat River.

Shallow water, *Ranunculus aquatilis;* inter-ridge pond; lower Shagamu River area.

Deep water Nuphar ponds (50%) in lowshrub bog (35%) with graminoid edges (10%); south interior.

Appendices

Crab spider on *Cypripediuim reginae*, Keogami River cedar swamps.

Appendix A

Keys to Wetland Types

Adapted from Riley 1994a,b; after Zoltai *et al.* (1975), Jeglum *et al.* (1974), Jeglum and Boissonneau (1977) and Tarnocai (1979), and incorporating reviews of other sources (*e.g.*, Ahti and Hepburn 1967, Maycock 1979, Riley and McKay 1980). The wetland site-type catalogue, App. C, is organized by these types.

FORMATION	**BOG**
SUBFORMATION	TREED
PHYSIOGNOMIC GROUP	*LOWSHRUB*
DOMINANCE TYPE	*PICEA MARIANA-CHAMAEDAPHNE CALYCULATA*
Site Type	*Picea mariana*[26] - *Chamaedaphne calyculata*[42] - *Sphagnum fuscum*[77]

These units are hierarchical, different levels having varying utility for particular purposes. For example, formations/subformations have been mapped at airphoto and satellite-image scales, and physiognomic groups at airphoto and OBM scales, and for inventory, habitat and resource mapping. The order of normal use is subformation-physiognomic group-formation, e.g., TREED LOWSHRUB BOG. Dominance and site type are used at finer scales, based on quantitative survey. Terms can be abbreviated and complexed to describe particular cover percents or combinations/patterns, *e.g.*, TREED^{26} LOWSHRUB^{26} BOG as T^{26}ls^{26}B, and a mix of types such as TlsB^{50}-OgB^{30}-OpB^{15} (abbreviations noted below).

A. KEY TO FORMATIONS

Clay plains, basins, depressions, slopes, seeps, drains, floodplains, river and lake shores, and seasonally or tidally flooded areas. Water table at, near or above surface for part of the year, saturated long enough to support features such as hydric or organic soils, or hydrophilic vegetation. Water levels can range from flooded spring or tidal conditions to summer drought conditions with water tables more than 50cm below ambient land or peat surface, or frozen as permafrost. .... ***WETLAND***

1a. Well-defined aquatic basins or shoreline zones often transitional to deep waters; inorganic or organic substrates. Vegetation submerged, floating or emergent, in standing water less than 2m deep, or on exposed substrate during water-drawdown periods, such as low tides or summer drought. Periodically or permanently flooded by silt- or nutrient-enriched lake or river waters. In sites exposed to wave or current, mineral soils normally dominate, whereas peat and/or muck may accumulate in less disturbed sites.

2a. Waterbodies covered more than 75% with open water, usually less than 2m deep and associated with flowing or standing lakes, rivers or ponds; with sparse floating,submergent or emergent vegetation (less than 25% cover by emergents.) Sites withstanding water up to 2m are **SHALLOW (sW)** and those deeper than 2m are **DEEP WATER (dW)**, and are transitional to aquatic site types (App. C) .... **WATER (W)**

2b. Unsolidated open, flat or depressed surfaces dominated by emergent herbs, sedges, grasses, cattails or reeds (>25% cover), or low shrubs; interspersed in standing water or free-standing at low water levels. With occasional small pools and channels, and with exposed patches of mineral or organic soils during

seasonal (or tidal) water drawdowns. Often associated with, and periodically flooded by, the mineral-enriched groundwaters of streams or rivers, flowing lakes, or marine flats or terraces (Often contiguous with or grading into THICKET SWAMP, with a shrub element of up to 25%). . . . . **MARSH (M)**

(MARSH includes the drier, semi-terrestrial **MEADOW MARSH (MM)**, from which it also differs by the presence, normally, of standing water and less diverse, more open vegetation. Both MARSH and MEADOW MARSH can occur on organic or mineral substrates. The gradients between them can be transitional in tidal and littoral mineral-soil sites where water drawdown or incursion varies seasonally or tidally.)

1b. Less-defined basins in which open standing water is absent or restricted to scattered small pools; substrate of saturated (or seasonally dry) peat more than 30-40cm deep. . . . . ***PEATLAND***

3a. Predominantly ombrotrophic (rain-derived) or weakly minerotrophic peatland, developed on poorly decomposed, acidic *Sphagnum* peat. Surface is isolated from mineral substrates and ground water, and the water 10cm below water table is usually <pH 5.2, higher where dry by drought, and significantly lower than pH <4.4 where sites are strictly ombrotrophic (and Ca levels <2ppm). Low diversity of plants and insects.

4a. Level, gradually raised, domed or sloping surfaces normally with a hummock-hollow topography, usually with continuous moss cover dominated by *Sphagnum* (*e.g., S. fuscum* in hummocks, with sparse graminoids, ericaceous shrubs and black spruce (or tamarack in transitional sites), or with wet blanket coverage by other *Sphagnum* spp., accompanied by graminoid ground cover and mostly ericaceous shrubs. With or without discontinuous permafrost or seasonal ice lenses; regularly with incipient palsa forming north of about 51°N. . . . . **BOG (B)**

4b Erratic topography of perennial permafrost peat eruptions (palsa) or smoother raised permafrost terrain of coalesced palsas (peat plateau) usually rising more than 1m above ambient ground level; with more or less continuous frozen peat cores, and usually patterned with interstitial drainways (deep in bog types, shallow or absent in fen types). Surface vegetation can be bog-like (lichens, ericaceous shrubs, without trees or with *Picea mariana* up to 25% cover) or fen-like (*Scorpidium* spp., *Carex rariflora* types on raised and unpatterned permafrost plains). PEAT PLATEAU can support thermokarst lake systems, across which lakes and ponds erode downwind, with distinct zones of peat erosion and deposition.) . . . . **PEAT PLATEAU (PP) and PALSA (P)**

3b. Predominantly minerotrophic wetland, developed on woody, graminoid or brown-moss peat or, if with abundant *Sphagnum* at the surface, not usually underlain by a strata of *Sphagnum* peat >30cm thick. Enriched by lateral or groundwater inputs of mineral-soil waters. High diversity of plants and insects.

5a. Wooded, with more than 25% cover by trees or shrubs >135cm. Usually with hummocky surfaces broken by wet interstitial hollows, or relatively flat but with spring-flooded pools. Substrates include mixtures of transported mineral, organic sediments, or *in situ* peat (woody or with *Sphagnum* at surface). May be seasonally flooded or flooded by beaver, or with interstitial hollows of standing water and hummocks associated with deadfall or the bases of trees or shrubs. (To the south, SWAMP can be distinguished from high-density TREED BOG by its location on the wetter water margins of peatlands, or by the occurrence of understorey *Alnus rugosa* or *Salix* spp, indicating minerotrophy. In SWAMP there can also be surficial *Sphagnum* peat less than 30cm thick, and more vigorous growth of trees, often those >10cm DBH more than 25% cover. Northern river and stream levees can be formed of alternating alluvia of peat and ice, and be transitional between forest and SWAMP.) . . . . **SWAMP (S)**

5b. More sparsely wooded or open, usually with level or depressional surfaces except for low shrub hummocks in open sites, and low root or stump hummocks in treed sites, and with or without surface water in the interstitial hollows dominated by grasses and/or mostly non-ericaceous shrubs. Tree cover may reach 25% (*Larix laricina, Thuja occidentialis*) but is usually >10m in height and with an understorey of low shrubs and/or graminoids rather than taller alder or willow. In untreed sites, pools of open water or drainage tracks are often present. Surface patterns include parallel ribbing, netted pools and raised islands (often BOG), and linear drainways and regularly dispersed pools. Various *Sphagnum* spp. present where water pH is between 5.2 and 6.0, but more neutral sites (pH >5.5) support brown mosses (*Campylium stellatum, Aulocomnium palustre, Drepanocladus revolvens, Tomenthypnum nitens, Scorpidium scorpioides, Palludella squarrosa, Calliergon giganteum*). In marl sites, surface water pHs are often in excess of 7.0. .... **FEN (F)**

FEN may be weakly minerotrophic, with few indicator species present, and *Sphagnum* and *Picea mariana* dominating, particularly in hummock phases. Such sites are successionally transitional to BOG and can be extensive. They can be termed **POOR FEN (PF)**. This transition is developmental rather than physiognomic, and is not a formation of equivalent status to others. Such sites are here termed FEN, based on indicator species at even low frequencies (App. D). Interpretation of POOR FEN based on airphotos is unreliable.

B. KEY TO SUBFORMATIONS

BOG, FEN, PEAT PLATEAU (PALSA)

1a. Cover by individual trees taller than 135cm less than 10% .... **OPEN (O^x)**
(Note: Percent tree-cover can noted as superscript, e.g., 8% as O^8)

1b. Cover by individual trees taller than 135cm more than 10% (rarely 40%); trees >10cm DBH <10%. .... **TREED (T^x)**

2a. Cover by trees taller than 135cm between 10% to 15% .... **Low-density TREED (T(ld))**

2b. Cover by trees taller than 135cm between 15% to 25%, occasionally more than 25% .... **Medium-density TREED (T(md))**

2c. Cover by trees taller than 135cm more than 25%; BOG or FEN species such as *Ledum groenlandicum* dominate in the understorey, and SWAMP species such as alder or willows not present. Transitional to SWAMP, and unreliably distinguished on airphotos. .... **High-density TREED (T(hd))**

MARSH, MEADOW MARSH, WATER

1a. Sites within the marine (salt) influence of Hudson and James bays. .... **COASTAL (C)**

1b. Sites subject to tides and the freshwater influence of major rivers. .... **ESTUARINE (E)**

1c. Interior sites beyond the marine influence of Hudson and James bays. .... **FRESHWATER (FW)**

C. KEY TO PHYSIOGNOMIC GROUPS

BOG, FEN, PEAT PLATEAU (PALSA)

Where more than one physiognomy applies, the shrub layer takes precedence over the graminoid/herb and *Sphagnum*-lichen layers; the graminoid/herb layer takes precedence over *Sphagnum*-lichen; and *Sphagnum* and lichen is used where neither shrub nor graminoid/herb layer meets the cover levels below.

1a. Low or dwarf shrubs less than 135cm tall more than 25% cover, or tall shrubs 10% to 30% (rarely to 40%) cover. Where the height of shrub cover is indiscernible from airphotos or when field data are otherwise unavailable, a generic notation **SHRUB(sh)** can be used.

2a. Shrubs over 135cm tall 10% to 30% (rarely to 40%) cover. Shrubs include *Chamaedaphne calyculata* (B,F), *Kalmia angustifolia* (B), shrub *Thuja occidentalis* (F), *Betula pumila* (F,MM), *Salix pedicellaris* (F), *S. candida* (MM), *Myrica gale* (MM). . . . . **Shrub-rich (sr)**

2b. Shrubs 20 to 135cm tall >10% cover and having the main visual impact, although there may also be significant graminoid component. Taller shrubs can be present but <10% cover. Shrubs include those above, as well as layered or candelabra *Picea mariana* (<135cm tall), and *Ledum groenlandicum* (B,F), *Andromeda glaucophylla* (B,F), *Salix candida* (F), *Potentilla fruticosa* (F) and *Myrica gale* (F). Sub-shrubs such as *Vaccinium oxycoccus, Rubus pubescens, R. acaulis* and *R. chamaemorus* are not included in shrub cover values. . . . . **Lowshrub (ls)**

2c. Shrubs less than 20cm tall more than 10% cover. On northern PEAT PLATEAU, PALSA, BOG and FEN, these represent extremes of climatic exposure and/or nutrient ombrotrophy. Semi-shrubs are not covered in shrub cover values. . . . . **Dwarf-Shrub (ds)**

2d. Most conspicuous visual impact is lichen cover (*Cladina* spp.) over 45% to 50% cover. . . **Lichen-rich (lr)**

1b. Shrubs not present or present at cover values less than those indicated above.

3a Firm peatland above water most of the year.

4a. Conspicuous graminoid layer (sedges, grasses, reeds) more than (8% to) 10% cover; graminoid cover exceeds shrub cover percentage. Characteristic species are *Carex aquatilis* (B,F), *C. chordorrhiza* (F), *C. exilis* (F), *C. lasiocarpa* (F), *C. limosa* (B,F), *C. livida* (F), *C. oligosperma* (B), *C. magellanica* (B), *C. rariflora* (B), *Eriophorum vaginatum* (B), *Scirpus cespitosus* (F,B), and *S. hudsonianus* (F). Included in this graminoid layer are the peatland forbs and semi-shrubs (above). . . . . **Graminoid (g)**

4b. Sphagnum mosses dominant at surface; shrubs, herbs and graminoids less than 10% cover. . . . . **Sphagnum (sp)**

3b. Small waterbodies interspersed with peatlands, often with a patterned distribution; usually contiguous with Open BOG and FEN. . . . . **Pool (p)**

MARSH (and WATER)

1a. Closed graminoid and herb (and lowshrub) vegetation normally adjacent to coastal or shoreline emergent vegetation, and on wet floodplains, terraces and supratidal areas adjacent to open water systems. Usually seasonally flooded, flooded in the recent past (*e.g.*, by beaver), or subject to storm or neap tides. Graminoids normally dominate; *Calamagrostis canadensis, C. stricta, Carex aquatilis, C. lenticularis, C. saxatilis, C. viridula, Equisetum variegatum, Scirpus cyperinus*. . . . . **MEADOW MARSH (MM)**

2a. Shrubs over 135cm tall 10% to 30% cover, but also normally with sedges, grasses, reeds or cattails present. Often the more or less unconsolidated edge of THICKET SWAMP or MARSH. Shrubs include *Salix* spp, *Myrica gale, Betula pumila*. . . . . **Shrub-rich (sr)**

2b. Shrubs shorter than 135cm (including dwarf and semi-shrubs) more than 10% cover and having the main visual impact, although sites may also have a graminoid component. Shrubs include those above, and *Arctostaphylos rubra, Salix brachycarpa, S. candida, S. glauca, S. planifolia, Vaccinium uliginosum*. . . . . **Lowshrub (ls)**

1b. Emergent graminoids and shrubs greater than 25% cover, in or adjacent to shallow water pools, channels, shores and coasts; commonly interspersed as clumps of rooted or uncolidated and floating vegetation, with water channels between, or with open water beneath a canopy of sedges, grasses, reeds or cattails. Where ground data are unavailable, or for airphoto interpretation, the generic term **EMERGENT (e)** marsh may be used. . . . . **MARSH (M)**

3a. Emergent cover 75%-100%; standing water, muck or mud flats beneath canopy or between clumps. More-or-less continuous stands of tall emergents, with water up to 1m in floodstages and less during summer drawdown. Dominant freshwater species include *Arctophila fulva, Carex aquatilis, C. lasiocarpa, C. limosa, C. recta, C. retrorsa, C. utriculata, Eleocharis smallii, Equisetum fluviatile, Hippuris vulgaris, Petasites sagittatus, Phragmites australis, Potentilla palustris.* (Also applies to WATER up to 2m deep, with emergent or submergent vegetation.) .... **Shallow (s)**

3b. Canopy cover 25-75%; standing water, muck or mud flats beneath canopy or between clumps. Extreme variation in water levels, ranging from water levels at the surface (*e.g.*, after summer drawdowns) to standing water up to 2m deep. Dominant species include *Scirpus acutus, Typha latifolia.* (Also applies to WATER >2m deep, primarily submergent vegetation.) .... **Deep (d)**

The dominant species above are typical of interior **FRESHWATER MARSH**. **MARSH** and **MEADOW MARSH** vary significantly in dominance closer to the maritime coast, where they cover extensive areas as either **COASTAL** or **ESTUARINE MARSH** (Riley and McKay 1980; Glooschenko 1980a,b).

1a. MARSH subject to spring high tides and other exceptional tides ,and consequent marine icescouring; grading away from coastal areas into FRESHWATER MARSH and MEADOWMARSH; often broken with pools with elevated salinity and salt-reliant plants (halopytes). .... **Supratidal (sup)**

Dominant species of COASTAL Supratidal MEADOW MARSH include *Calamagrostis stricta, Carex glareosa, C. paleacea, Deschampsia cespitosa, Eleocharis smallii, Festuca rubra, Hippuris vulgaris, Juncus balticus, Myriophyllum sibiricum, Potamogeton filiformis, Scirpus americanus, S. rufus, Senecio congestus* and *Zannichellia palustris.*

Dominant species of ESTUARINE Supratidal MEADOW MARSH include *Anemone canadensis, Carex recta, C. limosa, Equisetum variegatum, Festuca rubra, Juncus balticus* and *Rhinanthus crista-galli.*

1b. MARSH subject to regular tidal influence; grading into Supertidal MEADOW MARSH but usually with emergent beach-ridge deposits or deposits of tidal debris forming some upper boundary between 'regular' vs. 'exceptional' tidal activity; halophytic plants dominating, except in ESTUARINE sites ameliorated by freshwater inputs. .... **Intertidal (int)**

Dominant species of COASTAL Intertidal MARSH include *Carex mackenziei, C. paleacea, C. subspathacea, Eleocharis smallii, Hippuris tetraphylla, Potemogeton filiformis and P. pectinatus, Potentilla anserina* var. *groenlandica, Puccinellia phryganodes, Scirpus maritimus, Senecio congestus* and *Zannichellia palustris.* Halophytes such as *Plantago maritima* and *Salicornia europaea* are frequent associates.

Dominant species of ESTUARINE Intertidal MARSH include *Bidens hyperborea, Carex paleacea, Equisetum fluviatile, Hippuris vulgaris, Juncus nodosus, Lysimachia thyrsiflora, Potentilla anserina* var. *groenlandica, Puccinellia phryganodes, Sagittaria latifolia, Scirpus americanus, S. rufus, S. validus* and *Senecio congestus.*

SWAMP

1a. Tree species dominant.

2a. Conifers dominant (*Picea mariana, Larix laricina, Thuja occidentalis*). .... **Conifer (c)**

Conifer SWAMP on peatland varies considerably in nutrient status and dominance types. In the merchantable SWAMP of the southernmost HBL, nutrient-related classifications would be very similar to the Forest Ecosystem Operational Groups (OGs) developed for the Northern Clay Belt (Jones *et al.* 1983); OG11, *Picea mariana–Ledum groenlandicum*; OG12, *Picea mariana–Alnus rugosa*–herb-poor; OG13, *Picea mariana* (*Larix laricina, Thuja occidentalis*)–*Alnus rugosa*–herb-rich.)

2b. Broadleaf deciduous trees dominant (*Fraxinus nigra, Populus balsamifera, Ulmus americana*) .. **Broadleaf (b)**

2c. Mixed conifer and broadleaf trees dominant .... **Mixed (m)**

1b. Tree species less than 25% cover and shrubs over 135cm tall more than 25% (*Alnus and Salix* spp., *Betula pumila, Cornus stolonifera*). Grades into shrub-rich MEADOW MARSH .... **Thicket (t)**

Appendix B

Summary of Dominance Types, Distribution, Permafrost

FORMATION / SUBFORMATION / *PHYSIOGNOMIC GROUP* / DOMINANCE TYPE	Ecoregion	Permafrost (c = continuous, d = discontinuous, n = not noted)
PEAT PLATEAU	**0E, 1E**	**c**
TREED		
TREED LICHEN-RICH LOWSHRUB PEAT PLATEAU		
PICEA MARIANA - LEDUM GROENLANDICUM - CLADINA	1E	c
TREED LOWSHRUB PEAT PLATEAU		
PICEA MARIANA - LEDUM GROENLANDICUM	1E	c
OPEN		
OPEN LICHEN-RICH LOWSHRUB PEAT PLATEAU		
LEDUM - CLADINA	0E,1E	c
RHODODENDRON LAPPONICUM - LEDUM DECUMBENS - CLADINA	1E	c
OPEN LOW SHRUB PEAT PLATEAU		
CHAMAEDAPHNE CALYCULATA - CLADINA	0E	c
BOG	**0E,1E,2E**	**c,d,n**
TREED		
TREED SHRUB-RICH BOG		
PICEA MARIANA - CHAMAEDAPHNE CALYCULATA	2E	d,n
PICEA MARIANA - KALMIA ANGUSTIFOLIA	2E	d,n
TREED LOWSHRUB BOG		
PICEA MARIANA	1E,2E	n
PICEA MARIANA - CHAMAEDAPHNE CALYCULATA	1E,2E	n
PICEA MARIANA - LEDUM GROENLANDICUM	2E	n,d
TREED LICHEN-RICH LOWSHRUB BOG		
PICEA MARIANA - CLADINA	1E,2E	n
TREED GRAMINOID BOG		
PICEA MARIANA - CAREX OLIGOSPERMA	2E	n
OPEN		
OPEN SHRUB-RICH BOG		
PICEA MARIANA - THUJA OCCIDENTALIS (shrub)	2E	n
OPEN LOWSHRUB BOG		
CHAMAEDAPHNE CALYCULATA	0E,1E,2E	c,n
CHAMAEDAPHNE CALYCULATA - GRAMINOIDS	2E	c,n
OPEN LICHEN-RICH LOWSHRUB BOG		
CHAMAEDAPHNE CALYCULATA - CLADINA	0E,1E,2E	d,n
LEDUM GROENLANDICUM - CLADINA	2E	d
OPEN GRAMINOID BOG		
CAREX AQUATILIS	0E	c,n
CAREX LIMOSA	0E,2E	c,n
CAREX MAGELLANICA	1E,2E	n
CAREX OLIGOSPERMA	1E,2E	n
CAREX RARIFLORA	0	c
ERIOPHORUM VAGINATUM	1E,2E	c,n
RHYNCHOSPORA ALBA	2E	n
SCHEUCHZERIA PALUSTRIS	1E,2E	n
SCIRPUS CESPITOSUS	0E,1E,2E	c,n
OPEN SPHAGNUM BOG		
SPHAGNUM FUSCUM	2E	d,n
SPHAGNUM MAGELLANICUM	2E	d
SPHAGNUM NEMOREUM	2E	n
OPEN POOL BOG		
CLADOPODIELLA FLUITANS	2E	d,n
SPHAGNUM MAGELLANICUM - CAREX OLIGOSPERMA	2E	n
SPHAGNUM LINDBERGII	1E	n
SPHAGNUM MAJUS	1E,2E	n
FEN	**0E,1E,2E**	**c,d,n**
TREED		
TREED SHRUB-RICH FEN		
LARIX LARICINA - BETULA PUMILA	0E,2E	n
LARIX LARICINA - BETULA PUMILA - CHAMAEDAPHNE CALYCULATA	1E,2E	n

FORMATION SUBFORMATION *PHYSIOGNOMIC GROUP* DOMINANCE TYPE	Ecoregion	Permafrost c = continuous d = discontinuous n = not noted
TREED LOWSHRUB FEN		
LARIX LARICINA - ANDROMEDA GLAUCOPHYLLA	2E	n
LARIX LARICINA - BETULA PUMILA	0E,1E,2E	n
LARIX LARICINA - SALIX CANDIDA	0E	n
THUJA OCCIDENTALIS - LARIX LARICINA - BETULA PUMILA	2E	n
THUJA OCCIDENTALIS - MYRICA GALE	2E	n
TREED GRAMINOID FEN		
LARIX LARICINA - CAREX CHORDORRHIZA - CAREX LIMOSA	2E	n
LARIX LARICINA - CAREX LASIOCARPA	2E	n
LARIX LARICINA - CAREX LIMOSA - SCIRPUS HUDSONIANUS	1E,2E	n
THUJA OCCIDENTALIS - SCIRPUS HUDSONIAUS - SCIRPUS CESPITOSUS	2E	n
OPEN		
OPEN SHRUB-RICH FEN		
LARIX LARICINA (shrub) - BETULA PUMILA	1E	n
SALIX PEDICELLARIS	1E	n
OPEN LOWSHRUB FEN		
ANDROMEDA GLAUCOPHYLLA	2E	n
BETULA PUMILA	0E,2E	n
CHAMAEDAPHNE CALYCULATA	2E	n
LARIX LARICINA (shrub) - BETULA PUMILA	0E	c,n
MYRICA GALE	2E	n
POTENTILLA FRUTICOSA	2E	n
OPEN DWARF-SHRUB FEN		
ARCTOSTAPHYLOS ALPINA	0E	c
VACCINIUM ULIGINOSUM	0E	c
OPEN GRAMINOID FEN		
CAREX AQUATILIS	0E	c,n
CAREX CHORDORRHIZA	0E,1E,2E	c,n
CAREX EXILIS	2E	n
CAREX LASIOCARPA	2E	n
CAREX LIMOSA	0E,1E,2E	c,n
CAREX LIVIDA	0E,1E	n
CAREX SAXATILIS	0E	c
CAREX UTRICULATA	2E	n
SCIRPUS CESPITOSUS	0E,1E,2E	c,n
SCIRPUS HUDSONIANUS	1E	n
OPEN POOL FEN		
ERIOPHORUM CHAMISSONIS	0E	d
CAREX LIMOSA	0E,1E,2E	c,n
MENYANTHES TRIFOLIATA	2E	d,n
RYNCHOSPORA ALBA	2E	n
SCORPIDIUM SCORPIOIDES	2E	d,n

FORMATION SUBFORMATION *PHYSIOGNOMIC GROUP* DOMINANCE TYPE	Ecoregion	Permafrost c = continuous d = discontinuous n = not noted
SWAMP	**0E,1E,2E**	**c,d,n**
CONIFER SWAMP		
LARIX LARICINA	2E	n
PICEA MARIANA -LEDUM GROENLANDICUM	1E,2E	d,n
PICEA GLAUCA - ABIES BALSAMEA	2E	d
THUJA OCCIDENTALIS	2E	n
BROADLEAF SWAMP		
POPULUS BALSAMIFERA	1E,2E	n
ULMUS AMERICANA - FRAXINUS NIGRA	2E	n
THICKET SWAMP		
ALNUS CRISPA	1E	n
ALNUS RUGOSA	1E,2E	c,n
CORNUS STOLONIFERA	2E	n
MYRICA GALE	2E	n
SALIX CORDATA	2E	n
SALIX EXIGUA	2E	n
SALIX GLAUCA	2E	n
SALIX PELLITA	1E,2E	n
SALIX PLANIFOLIA	0E,2E	n
SALIX SERISSIMA	2E	n
MARSH	**0E,1E,2E**	**c,n,d**
FRESHWATER		
SHALLOW MARSH		
ARCTOPHILA FULVA	0E	c
CAREX AQUATILIS	0E	c
CAREX LASIOCARPA	1E	n
CAREX LIMOSA	2E	n
CAREX RECTA	2E	n
CAREX RETRORSA	2E	n
CAREX UTRICULATA	2E	n,d
ELEOCHARIS SMALLII	1E,2E	n
EQUISETUM FLUVIATILE	0E	c
HIPPURIS VULGARIS	0E,1E	c,n
MENYANTHES TRIFOLIATA	0E,2E	c,n
PETASITES SAGITTATUS	0E	c
PHRAGMITES AUSTRALIS	2E	n
POTENTILLA PALUSTRIS	2E	n
DEEP MARSH		
SCIRPUS ACUTUS	2E	n
TYPHA LATIFOLIA	2E	n
MEADOW MARSH		
ALOPECURUS AEQUALIS	2E	n
CALAMAGROSTIS CANADENSIS	2E	n
CALAMAGROSTIS STRICTA	0E	c
CAREX AQUATILIS	0E,1E,2E	c,d,n
CAREX LENTICULARIS	2E	n
CAREX SAXATILIS	0E,1E	c,n

FORMATION **SUBFORMATION** ***PHYSIOGNOMIC GROUP*** DOMINANCE TYPE	**Ecoregion**	**Permafrost** c = continuous d = discontinuous n = not noted
CAREX VIRIDULA	2E	n
EQUISETUM ARVENSE	0E	c
EQUISETUM VARIEGATUM	0E	c
SCIRPUS CYPERINUS	1E	n
SHRUB-RICH MEADOW MARSH		
SALIX - MYRICA GALE - BETULA PUMILA	2E	n
LOWSHRUB and DWARF - SHRUB MEADOW MARSH		
BETULA PUMILA	0E	c
MYRICA GALE	0E	c
SALIX BRACHYCARPA	0E	c
SALIX CANDIDA	0E,2E	c,n
SALIX GLAUCA	0E	c
SALIX PELLITA	2E	n
SALIX PLANIFOLIA	0E	c
ESTUARINE		
SUPRATIDAL MEADOW MARSH		
ANEMONE CANADENSIS	2E	n
AGROSTIS GIGANTEA	2E	n
CAREX RECTA	2E	n
CAREX LIMOSA	2E	n
EQUISETUM VARIEGATUM	2E	n
FESTUCA RUBRA	2E	n
JUNCUS BALTICUS	2E	n
RHINATHUS CRISTA-GALLI	2E	n
INTERTIDAL MARSH		
BIDENS HYPERBOREA	2E	n
CAREX PALEACEA	2E	n
CAREX RECTA	2E	n
EQUISETUM FLUVIATILE	2E	n
HIPPURIS VULGARIS	2E	n
JUNCUS NODOSUS	2E	n
LYSIMACHIA THYRSIFLORA	2E	n
POTENTILLA ANSERINA var. GROENLANDICA	2E	n
PUCCINELLIA PHRYGANODES	2E	n
SAGITTARIA LATIFOLIA	2E	n
SCIRPUS AMERICANUS	2E	n
SCIRPUS VALIDUS	2E	n
SENECIO CONGESTUS	2E	n
COASTAL		
SUPRATIDAL MEADOW MARSH		
CALAMAGROSTIS STRICTA	2E	n
CAREX GLAREOSA	0E,2E	c,n
CAREX PALEACEA	2E	n
DESCHAMPSIA CESPITOSA	2E	n
ELEOCHARIS SMALLII	2E	n
FESTUCA RUBRA	0E,2E	c,n
HIPPURIS VULGARIS	0E,2E	c,n
JUNCUS BALTICUS	0E.2E	n
MENYANTHES TRIFOLIATA	2E	n
MYRIOPHYLLUM SIBIRICUM	0E,2E	c,n
PETASITES SAGITTATUS	0E	n
POTAMOGETON FILIFORMIS	2E	n
SCIRPUS AMERICANUS	2E	n
SCIRPUS RUFUS	1E, 2E	n
SENECIO CONGESTUS	1E, 2E	n
ZANNICHELLIA PALUSTRIS	0E,2E	n
INTERTIDAL MARSH		
CAREX GLAREOSA	0E	c
CAREX MACKENZIEI	0E,2E	c,n
CAREX PALEACEA	1E,2E	n
CAREX SUBSPATHACEA	0E	c
ELEOCHARIS SMALLII	1E,2E	n
HIPPURIS TETRAPHYLLA	0E,2E	c,n
POTAMOGETON FILIFORMIS - POTAMOGETON PECTINATUS	2E	n
POTENTILLA ANSERINA var GROENLANDICA	0E	c
PUCCINELLIA PHRYGANODES	0E,1E,2E	c,n
SCIRPUS MARITIMUS	2E	c,n
SENECIO CONGESTUS	0E,2E	c,n
ZANNICHELLIA PALUSTRIS	2E	n
WATER		
SHALLOW WATER		
MENYANTHES TRIFOLIATA	2E	n
MYRIOPHYLLUM SIBIRICUM	0E	c
POTAMOGETON ALPINUS	1E	n
POTAMOGETON FILIFORMIS	0E,2E	c,n
POTAMOGETON GRAMINEUS	2E	n
POTAMOGETON RICHARDSONII	0E	c
RANUNCULUS AQUATILIS (s.l.)	0E,1E	c,n
RANUNCULUS GMELINII	0E	c
DEEP WATER		
POTAMOGETON	1E,2E	n
NUPHAR	1E,2E	n
ZOSTERA (Coastal offshore)	1E,2E	n

Appendix C
Catalogue of Wetland Site Types

Original and referenced site-type data, with depth-to-water, surface-water pH, peat depth and location. Sites types in the catalogue that are represented by three or more samplings are presented as data ranges and averages. Site types with only one or two sample sites are presented as raw data.

References to depth of active layer imply sites at which ice was not penetrated by peat rods, sites with continuous permafrost (=ice greater than ±30cm). The presence of penetrated ice lenses (=<±30cm thick) indicates sites with seasonally thinned, discontinuous permafrost.

Sample sites referred to in the catalogue numbered and indicated on Fig 6. Other sample sites are referenced as general location (*e.g.*, SW James Bay) or by literature source (*e.g.*, Maycock 1979), and these general locations are also indicated on Fig. 6. More detailed locations of quantitative sample sites are referenced on 1:250,000 N.T.S. mapsheets stored digitally at OMNR, Ontario Parks, Peterborough, and with the author.

Nomenclature for vascular plants follows Riley (2003); and *Flora North America* synonyms are listed in Appendix E. *Sphagnum* nomenclature follows *Flora North America* (2007, vol. 27).

FORMATION *PHYSIOGNOMIC GROUP* DOMINANCE TYPE Site Type (% cover, ranges and means)	**Depth-to-water** range (mean) (cm)	**pH**	**Peat depth** range (mean) (m)	**Sample sites** Fig. 6 except as indicated	**Ecoregion**
PEAT PLATEAU					
TREED					
TREED LICHEN-RICH LOWSHRUB PEAT PLATEAU					
PICEA MARIANA - LEDUM GROENLANDICUM - CLADINA					
Cladina spp. 95,100 - *Ledum groenlandicum* 10,20 - *Picea mariana* 10,10	Unsaturated	Dry	Permafrost (>3.0m, with active layer 25-35cm)	334B 305A	1E 1E
TREED LOWSHRUB PEAT PLATEAU					
PICEA MARIANA - LEDUM GROENLANDICUM					
Pleurozium schreberi 90 - *Cladina* spp. 30 - *Ledum groenlandicum* 20 - *Picea mariana* 20 - *Rubus chamaemorus* 7	Unsaturated	Dry	Permafrost	Aquatuk	1E
OPEN					
OPEN LICHEN-RICH LOWSHRUB PEAT PLATEAU					
LEDUM - CLADINA					
Cladina spp. 80,85 - *Ledum groenlandicum* 2,4 - *Ledum decumbens* 0,18	Unsaturated	Dry	Permafrost (3.4,>4.5m; active layers 25,70cm)	261D 602B	0E 1E
Cladina spp. - *Ledum decumbens* - *Vaccinium vitis-idaea* - *Epilobium angustifolium* (post-burn)	Unsaturated	Dry	Permafrost (active layer 30cm)	285	0E

FORMATION ***PHYSIOGNOMIC GROUP*** DOMINANCE TYPE Site Type (% cover, ranges and means)	**Depth-to-water** range (mean) (cm)	**pH**	**Peat depth** range (mean) (m)	**Sample sites** Fig. 6 except as indicated	**Ecoregion**
RHODODENDRON LAPPONICUM - LEDUM DECUMBENS - CLADINA					
Cladina spp.- *Rhododendron lapponicum* - *Ledum decumbens* - *Dryas integrifolia*	Unsaturated	Dry	Permafrost (active layer 55cm)	54°33'N, 83°41'W (43J-9A)	1E
OPEN LOWSHRUB PEAT PLATEAU					
CHAMAEDAPHNE CALYCULATA - CLADINA					
Sphagnum fuscum ^{60} - *Chamaedaphne calyclata* ^{25}- *Cladina* spp. ^{17} - *Picea mariana* ^{10}	25	3.9	Permafrost (active layer 35cm)	831A	0E

Note: OPEN GRAMINOID PEAT PLATEAU – This permafrost group is not segregated here because it is physiognomically indistinct from OPEN GRAMINOID FEN (dominated by *Carex aquatilis, C. limosa, C. saxatilis, Scirpus cespitosus, Scorpidium scorpioides* and *S. turgescens*; *e.g.*, 267, 270A, 322B, 828, and Kershaw 1974, series a,b) or OPEN GRAMINOID BOG (dominated *Carex rariflora, Cladopodiella fluitans, Sphagnum lindbergii*; *e.g.*, 261A,C, 285, 333B), from which they differ in being continuously flat, raised, flat and wet, without the hummock-hollow physiognomy of OPEN LOWSHRUB PEAT PLATEAU.

BOG

TREED					
TREED SHRUB-RICH BOG					
PICEA MARIANA - CHAMAEDAPHNE CALYCULATA					
Picea mariana $^{20-65}$ - *Chamaedaphne caluculata* $^{15-65}$ - *Sphagnum fuscum* $^{0-90}$ - *Pleurozium schreberi* $^{40-90}$ - *Kalmia angustifolia* $^{0-40}$ - *K. polifolia* $^{0-15}$ - *Rubus chamaemorus* $^{0-15}$ - *Smilacina trifolia* $^{0-35}$ - *S. recurvum* - *S. magellanicum*	15-45	3.0-4.0	2.0->4.0	–	south 2E

Note: More common south in ecoregion 3E (Jeglum and Boissonneau 1977), and grading into prevailing TREED LOWSHRUB BOG, and black spruce CONIFER SWAMP, which has peat generally £30cm and tree cover ≥25%. See Carleton and Maycock 1978:1169, for equivalent open spruce bog class.

PICEA MARIANA - KALMIA ANGUSTIFOLIA					
Sphagnum fuscum ^{60} - *Cladina rangiferina* ^{40} - *Kalmia angustifolia* ^{25} - *Picea mariana* ^{20} (Cowell *et al.* 1978)	2	-	3.0 (ice lens at 50cm)	Kinoje	2E
TREED LOWSHRUB BOG					
PICEA MARIANA					
Sphagnum fuscum ^{90} - *Picea mariana* ^{30,50} - shrubs<135 cm ^{7,10}	45	4.7,4.8	1.5	299B 454	1E 2E
PICEA MARIANA - CHAMAEDAPHNE CALYCULATA					
Sphagnum fuscum $^{60-(77)-90}$ - *Chamaedaphne calyculata* $^{23-(40)-60}$ - *Picea mariana* $^{18-(26)-40}$	15-(34)60 Some unsaturated	2.9-(4.1)-4.6	1.3-(2.4)->3.9	391C, 483A, 513C, 519, 527B, 534, 554C, 573B	2E
Sphagnum fuscum $^{40-(68)-90}$ - *Chamaedaphne calyculata* $^{35-(40)-45}$ - *Picea mariana* $^{10-(20)-35}$ - *Pleurozium schreberi* $^{0-(18)-55}$	25 One site unsaturated, one with ice lens	4.5-(4.9)-5.1	1.3-(1.6)-2.1	304A,368, 367B	1E

FORMATION *PHYSIOGNOMIC GROUP* DOMINANCE TYPE Site Type (% cover, ranges and means)	**Depth-to-water** range (mean) (cm)	**pH**	**Peat depth** range (mean) (m)	**Sample sites** Fig. 6 except as indicated	**Ecoregion**
Sphagnum fuscum 50 - *Chamaedaphne calyculata* 20 - *Picea mariana* 19	70	-	-	821	2E
Sphagnum rubellum 80 - *Chamaedaphne calyculata* 70 - *Picea mariana* 16	65	3.6	1.4	570C	2E
Sphagnum fallax 40-(63)-85 - *Chamaedaphne calyculata* 20-(41)-55 - *Picea mariana* 10-(16)-23	22-(29)-32	3.8-(4.2)-4.5	0.6-(2.3)-3.6	448,502B,495,489B	2E
Note: Transitional sites were sampled, similar to this except with *Larix* persisting, to the exclusion of *Picea*, *e.g.*,				494	2E
PICEA MARIANA - LEDUM GROENLANDICUM					
Sphagnum fuscum 95 - *Picea mariana* 25 - *Ledum groenlandicum* 25 - *Chamaedaphne calyculata* 5 (post-burn site)	30	4.1	2.2	495	2E
Sphagnum fuscum 60 - *Cladina alpestris* 40 - *Ledum groenlandicum* 40 - *Picea mariana* 20 (Cowell *et al.* 1978)	19	-	1.8 (ice lens present)	Kinoje	2E
Ledum groenlandicum 50 - *Cladina rangiferina* 30 - *Pleurozium schreberi* 25 - *Sphagnum rubellum* 25 - *Picea mariana* 20 (Cowell *et al.* 1978)	Unsaturated	-	2.6 (ice lens at 40cm)	Kinoje	2E
Picea mariana - Ledum groenlandicum 50 - *Chamaedaphne calyculata - Eriophorum spissum - Sphagnum fuscum* - . *Cladina* spp.	Unsaturated	3.4	1.5 (ice lens at 40cm)	Attawapiskat	2E
Pleurozium schreberi 70 - *Picea mariana* 60 - *Ledum groenlandicum* 20 (Cowell *et al.* 1978)	30	-	3.0 (ice lenses 45-160cm)	Kinoje	2E
Picea mariana 31 - *Sphagnum fuscum* 19 - *Ledum groenlandicum* 17 - *Cladium rangiferina* 12 (average, n=4; Jeglum and Cowell 1982)	40	3.5	2.2	Kinoje	2E
TREED LICHEN-RICH LOWSHRUB BOG					
PICEA MARIANA - CLADINA					
Cladina spp. 45 - *Sphagnum fuscum* 40 - *Rubus chamaemorus* 25 - *Picea mariana* 10 - *Ledum groenlandicum* 10 ("Hollow" phase of palsa field)	-	-	>2.0	Aquatuk	1E
Cladina spp. 65-(70)-75 - *Picea mariana* 15-(20)-25 - *Ledum groenlandicum* 1-(7)-12 - *Chamaedaphne calyculata* 4-(13)-25 - *Pleurozium schreberi*	25-(29)-32	4.1-(4.4)-5.0	1.0-(1.5)-1.8	319A,356B 403A	1E 2E
TREED GRAMINOID BOG					
PICEA MARIANA - CAREX OLIGOSPERMA					
Carex oligosperma 30-(43)-65 - *Picea mariana* 13-(16)-18 - *Sphagnum* fuscum 0-(22)-55 - *S. fallax* 0-(37)-85 *(S. magellanicum, S. riparium)*	17-(21)-25	4.1-(4.7)-4.9	0.8-(1.4)-2.1	403C,467C,482	2E
BOG					
OPEN					
OPEN SHRUB-RICH BOG					
PICEA MARIANA - THUJA OCCIDENTALIS (Shrubs)					
Sphagnum fuscum 85 - *Picea mariana* 20 - *Thuja occidentalis* 20 - *Dicranum undulatum* 10 - *Larix laricina* 5	12	4.1	2.2	437B	2E

FORMATION *PHYSIOGNOMIC GROUP* DOMINANCE TYPE Site Type (% cover, ranges and means)	**Depth-to-water** range (mean) (cm)	**pH**	**Peat depth** range (mean) (m)	**Sample sites** Fig. 6 except as indicated	**Ecoregion**
OPEN LOWSHRUB BOG					
CHAMAEDAPHNE CALYCULATA					
Sphagnum fuscum $^{60-(79)-95}$ - *Chamaedaphne calyculata* $^{10-(30)-50}$ - *Picea mariana* $^{0-(11)-45}$ - *Sphagnum fallax* $^{0-(9)-30}$	12-(31)-45	3.1-(4.0)-4.6	1.7-(2.4)-3.8	1B,6,412,434B,436, 455,457B,489A,491B, 467B,532A,493B,505, 513B,515,529,533,539B	2E
Sphagnum fuscum $^{65-(77)-90}$ - *Chamaedaphne calyculata* $^{8-(19)-25}$ - *Picea mariana* $^{0-(5)-20}$ - *S. fallax* $^{0-(6)-20}$ (- *S. lenense*)	10 (5 of 6 sites unsaturated, 2 with ice)	3.8-(4.5)-5.2 pH 5.7 at one dry site	0.7-(1.5)-2.2 (active layers of 17-38cm in sites with ice)	276,831A,833A 274B,366B, 369A,388B	0E 1E
Sphagnum fuscum ^{38} - *Picea mariana* ^{21} - *Chamaedaphne calyculata* ^{16} -*Kalmia angustifolia* ^{13} (average, n = 8; Jeglum and Cowell 1982)	25	3.6	2.6	Kinoje	2E
Sphagnum rubellum $^{80-(88)-100}$ - *Chamaedaphne calyculata* $^{20-(34)-70}$ - *Picea mariana* $^{0-(4)-10}$ - *S. fallax* $^{0-(13)-20}$	15-(21)-27	3.1-(4.4)-5.1	1.4-(2.3)->3.9	356A,292B 487,407B	1E 2E
Sphagnum fallax $^{50-(78)-100}$ - *Chamaedaphne calyculata* $^{6-(33)-50}$ - *Picea mariana* $^{0-(5)-10}$ - *S. magellanicum* $^{0-(11)-35}$	2-(11)-17	3.9-(4.6)-4.8	2.2-(2.8)-3.5	300B 416,440B,445B	1E 2E
Sphagnum lindbergii ^{70,100} - *Chamaedaphne calyculata* ^{15,30}	5,25	4.0,4.5	1.8,3.0	281 567	1E 2E
Sphagnum nemoreum $^{60-(84)-100}$ - *Chamaedaphne calyculata* $^{11-(18)-35}$ - *Sphagnum fallax* $^{0-(6)-20}$ - *Picea mariana* $^{1-(6)-10}$ - *Sphagnum fuscum* $^{0-(6)-20}$	12-(19)-25	2.8-(3.7)-4.9	1.6-(3.4)->3.9	466, 486B,453B, 507B,508B,522, 562C	2E
Sphagnum majus ^{60,40} - *S. fallax* ^{40,35} - *Chamaedaphne calyculata* ^{25,25} - *Carex limosa* ^{10,30}	5,15	4.6,5.0	1.7,3.9	423B,485B	2E
Sphagnum subsecundum ^{50} - *Chamaedaphne calyculata* ^{25} - *Sphagnum fuscum* ^{20} - *Scirpus hudsonianus* ^{20}	15	4.8	2.6	476B	2E
Sphagnum fuscum - *Cladina* spp. - *Chamaedaphne calyculata* - *Ledum groenlandicum*	-	5.5	0.9	Attawapiskat	2E
CHAMAEDAPHNE CALYCULATA - GRAMINOIDS					
Sphagnum nemoreum $^{65-(53)-95}$ and/or *Sphagnum majus* $^{30-(38)-85}$ - *Chamaedaphne calyculata* $^{10-(16)-20}$ - *Scheuchzeria palustris* $^{3-(11)-25}$ - *Carex limosa* $^{7-(9)-12}$	0-(4)-7	3.3-(3.8)-4.1	2.9-(3.3)-3.9	509,415,412	2E
Sphagnum magellanicum ^{55} – *Calliergon stramineum* ^{30} - *Chamaedaphne calyculata* ^{30} - *Scheuchzeria palustris* ^{10}	10	4.5	>3.9	473	2E
Sphagnum fuscum ^{40} - *S. nemoreum* ^{40} - *Chamaedaphne calyculata* ^{10} - *Carex aquatilis* ^{10}	0	5.0	(active layer 50cm over unpenetrated ice)	399	2E
Sphagnum fallax ^{90} - *Chamaedaphne calyculata* ^{20} - *Carex magellanica* ^{10} *Carex oligosperma* ^{10} - *Eriophorum* spp. ^{7} - *Carex utriculata* ^{5}	7	5.1	1.6	420	2E

Note: This Dominance Type is transitional to OPEN GRAMINOID BOG. As well, the above Dominance Types include species that, southward, characterize more fen-like peatlands, and are sometimes said to indicate 'poor fen,' a class that is not used here (see page 107).

FORMATION *PHYSIOGNOMIC GROUP* DOMINANCE TYPE Site Type (% cover, ranges and means)	**Depth-to-water** range (mean) (cm)	**pH**	**Peat depth** range (mean) (m)	**Sample sites** Fig. 6 except as indicated	**Ecoregion**
OPEN LICHEN-RICH LOWSHRUB BOG					
CHAMAEDAPHNE CALYCULATA - CLADINA					
Cladina spp.$^{45-(63)-90}$ - *Chamaedaphne calyculata* $^{5-(25)-50}$ - *Sphagnum fuscum* $^{0-(23)-50}$ - *Picea mariana* $^{5-(20)-36}$ - *Kalmia angustifolia* $^{0-(18)-15}$	14-(35)-65 (occasionally unsaturated)	2.9-(3.6)-4.9 (pH 5.5 at one dry site)	0.9-(2.3)-2.7	3A,221A, 226D, 401B,405B,556B, 558, 559,561,568B,569,572A	2E
Sphagnum fuscum ^{60,85} - *Cladina* spp. ^{45,50} - *Picea mariana* ^{10,18} -Ledum groenlandicum^{10}	15 at 1 site, unsaturated at other	4.5,4.7	>2.0 (active layers 40, 100cm over ice lenses)	320B 602C	0E 1E
Cladina spp. ^{48} - *Sphagnum fuscum* ^{40} - *Chamaedaphne calyculata* ^{22} - *Picea mariana* ^{8}	75	4.3	-	Kinoje	2E
LEDUM GROENLANDICUM – CLADINA					
Cladina mitis ^{45} - *Ledum groenlandicum* ^{20} (Cowell *et al.* 1978)	0	-	2.5 (ice lens at 43cm)	Kinoje	2E
OPEN GRAMINOID BOG					
CAREX AQUATILIS					
Sphagnum riparium ^{15,80} - *Carex aquatilis* ^{50,60} (*S. fallax* and/or *S. lindbergii*)	0	4.7,5.3	2.1 (active layer 25cm over ice at other site)	270C,344	0E
CAREX LIMOSA					
Cladopodiella fluitans $^{45-(48)-50}$ - *Sphagnum lindbergii* $^{25-(22)-40}$ - *S. nemoreum* $^{10-(10)-20}$ - *Carex limosa* $^{5-(8)-12}$ - *Rhynchospora alba* $^{1-(4)-5}$ - (*S. tenellum* also subdominant)	0	4.0-(4.6)-4.8	2.1-(2.8)-3.7	401A,446,568A	2E
Sphagnum majus ^{95,100} - *Carex limosa* ^{7,20} - *Sphagnum magellanicum* ^{1,5} - *Scheuchzeria palustris* ^{4,5}	5,5	4.5,4.7	2.6,2.8	457A,1A	2E
Sphagnum nemoreum $^{0-(43)-89}$ - *S. fallax* $^{0-(37)-70}$ - *Carex limosa* $^{12-(21)-30}$ - *Chamaedaphne calyculata* $^{3-(5)}$.	0-(1)-2	3.4-(3.8)-4.5	2.8-(3.1)-3.5	419,513A,518	2E
Sphagnum pulchrum ^{70,95} - *Carex limosa* $^{9-30}$ - *Sphagnum magellanicum* ^{1,25} – *Chamaedaphne calyculata* ^{6,7}	2,15	3.9,4.7	1.6,1.6	451,528	2E
Sphagnum papillosum ^{80} - *Cladopodiella fluitans* ^{20} - *Carex limosa* ^{20}	2	4.7	>3.9	460A	2E
Sphagnum annulatum ^{80,100} - *Carex limosa* ^{7,20} - *Scheuchzeria palustris* ^{5,0} - *Rhynchospora alba* ^{0,10}	5.5	5.1,5.1	2.1,.9	407A 380	2E
Sphagnum lindbergii ^{70,80} - (*Drepanocladus exannulatus* ^{25}) - *Carex limosa* ^{15,20}	-2,5	4.3,4.7	3.2 (other site with active layer 1m over ice)	285 445A	0E 2E
S. riparium ^{95} - *Carex limosa* ^{13} - *Vaccinium oxycoccus* ^{13}	0	5.3	2.7	278A	0E
CAREX MAGELLANICA					
Sphagnum riparium ^{100} - *Eriophorum chamissonis* ^{20} - *Carex magellanica* ^{15}	5	4.8	2.2	300A	1E
Sphagnum nemoreum ^{100} - *Smilacina trifolia* ^{15} - *Carex magellanica* ^{10} - *Eriophorum vaginatum* ^{5}	2	4.2	2.5	497C	2E
CAREX OLIGOSPERMA					
Sphagnum fallax $^{80-(88)-100}$ – *Carex oligosperma* $^{15-(42)-70}$ - *Chamaedaphne calyculata* $^{1-(4)-10}$	17-(13)-25	3.9-(4.1)-4.8	1.0-(2.1)-2.9	390A,452B,423A, 427A,477C,483B, 491A,465,467A	2E

FORMATION ***PHYSIOGNOMIC GROUP*** DOMINANCE TYPE Site Type (% cover, ranges and means)	**Depth-to-water** range (mean) (cm)	**pH**	**Peat depth** range (mean) (m)	**Sample sites** Fig. 6 except as indicated	**Ecoregion**
Sphagnum nemoreum $^{60\text{-}(84)\text{-}95}$ - *Carex oligosperma* $^{18\text{-}(36)\text{-}40}$ - *Chamaedaphne calyculata* $^{1\text{-}(8)\text{-}15}$	10-(11)-12	3.7-(3.9)-4.3	2.6-(3.2)-3.8	484B,502A, 527A,511A	2E
Sphagnum lindbergii ^{70,80} - *Carex oligosperma* ^{40,55} - *Chamaedaphne calyculata* ^{0,5}	12,12	3.5,3.8	2.3,2.5	3B,564B	2E
Sphagnum majus $^{40\text{-}100}$ - *Carex oligosperma* $^{20\text{-}50}$	2,10	4.4,4.6	1.7,3.7	485A,571A	2E
Sphagnum pulchrum ^{100} - *Carex oligosperma* ^{35}	0	4.2	2.2	297A	1E
Sphagnum tenellum ^{90} - *Carex oligosperma* ^{15}	5	4.6	2.6	499	2E
Sphagnum riparium ^{90} - *Carex oligosperma* ^{20}	7	4.2	2.2	493A	2E
Sphagnum rubellum ^{90} - *Carex oligosperma* ^{20}	10	4.2	2.4	458	2E
Sphagnum magellanicum ^{70} - *Carex oligosperma* ^{40}	2	4.8	1.9	391B	2E
CAREX RARIFLORA					
Sphagnum lindbergii ^{90} - *Carex rariflora* ^{7}	-1	4.2	2.4 (active layer 55cm)	261A	0E
ERIOPHORUM VAGINATUM					
Sphagnum nemoreum $^{60\text{-}(83)\text{-}100}$ - *Eriophorum vaginatum* $^{8\text{-}(18)\text{-}35}$ - *Carex limosa* $^{1\text{-}(4)\text{-}10}$	5-(8)-17	3.3-(3.9)-4.6	2.7-(3.0)-3.6	440A,443,447, 484A,507A,556A,565A	2E
Sphagnum lindbergii ^{95} - *Eriophorum vaginatum* ^{30} - *Chamaedaphne calyculata* ^{6} - *Carex oligosperma* ^{5}	5	3.9	3.5	453C	2E
Sphagnum magellanicum ^{75} - *S. majus* ^{15} - *Eriophorum vaginatum* ^{15} - *Carex limosa* ^{10}	10	3.6	2.6	1C	2E
Sphagnum riparium ^{90} - *Eriophorum vaginatum* ^{10}	5	5.4	(active layer 38cm over unpenetrated ice)	337	1E
Sphagnum rubellum ^{95} - *Eriophorum vaginatum* ^{10}	5	4.1	2.8	435	2E
RHYNCHOSPORA ALBA					
Cladopodiella fluitans ^{65,85} - *Rhynchospora alba* ^{20,15} - *Sphagnum* spp. ^{30,10} - *Scirpus cespitosus* ^{5,11}	2,5	4.0,5.1	2.5,3.5	508C,539A	2E
Sphagnum majus ^{25} - *S. pulchrum* ^{20} - *S. rubellum* ^{19} - *S. tenellum* ^{18} - *Rhynchospora alba* ^{18} – *Gymnocolea inflata* ^{14} (average, n = 5; Jeglum and Cowell 1982)	18	5.9	1.3	Kinoje	2E
SCHEUCHZERIA PALUSTRIS					
Sphagnum fallax ^{80,100} - *Cladopodiella fluitans* ^{20,30} - *Scheuchzeria palustris* ^{8,10} - *Carex limosa* ^{3,0}	2,5	4.1,4.6	3.8,0.7	511B 369B	2E 1E
Sphagnum nemoreum ^{90} - *Sphagnum pulchrum* ^{10} - *Scheuchzeria palustris* ^{6} - *Carex aquatilis* ^{4}	2	4.4	1.9	572B	2E
Drepanocladus exannulatus ^{80} - *Sphagnum centrale* ^{15} - *Scheuchzeria palustris* ^{10} - *Eriophorum gracile* ^{10}	0	4.5	1.9	391D	2E
Cladopodiella fluitans ^{60} - *Sphagnum lindbergii* ^{45} - *Scheuchzeria palustris* ^{10} - *Carex limosa* ^{5}	0	4.1	>1.5	Aquatuk	1E
SCIRPUS CESPITOSUS					
Cladopodiella fluitans $^{40\text{-}(73)\text{-}100}$ - *Scirpus cespitosus* $^{7\text{-}(24)\text{-}40}$ - *Sphagnum* spp. $^{0\text{-}(21)\text{-}60}$	0-(2)-5	4.4-(4.9)-5.1	2.4,>2.0	333B, 335,602A	0E 1E
Cladopodiella fluitans ^{30} - *Scirpus cespitosus* ^{15} - *Sphagnum lindbergii* ^{5} - *Andromeda polifolia* ^{5}	1	4.2	1.9 (active layer 0.5cm over ice)	261B	0E

FORMATION / ***PHYSIOGNOMIC GROUP*** / DOMINANCE TYPE / Site Type (% cover, ranges and means)	**Depth-to-water** range (mean) (cm)	**pH**	**Peat depth** range (mean) (m)	**Sample sites** Fig. 6 except as indicated	**Ecoregion**
Sphagnum lindbergii ^{80,82} - *Scirpus cespitosus* ^{5,15} - *Carex rariflora* ^{3,10}	0,5	4.8,4.8	1.8,2.4 (active layer 55cm at one ice-cored site)	261C 334A	0E 1E
Sphagnum majus $^{50-(83)-100}$ - *Scirpus cespitosus* $^{15-(23)-35}$ - *Chamaedaphne calyculata* $^{0-(3)-5}$	5,5	3.9-(4.6)-5.0	1.6-(2.2)-2.6	320A 305B 405A	0E 1E 2E
Sphagnum pulchrum ^{40} - *Scorpidium scorpioides* ^{20} - *Cladopodiella fluitans* ^{20} - *Scirpus cespitosus* ^{15} - *Carex limosa* ^{10}	0	5.1	1.5	348	1E
Sphagnum lindbergii ^{60} - *Cladopodiella fluitans* ^{40} - *Scirpus cespitosus* ^{40} - *Chamaedaphne calyculata* ^{10} - *Carex rariflora* ^{5} (**Note:** Hollow phase of palsa field.)	0	4.4	>2.0	Aquatuk	1E
Note: The above Dominance Types of OPEN GRAMINOID BOG include species that, southward, characterize more fen-like peatlands, and are sometimes said to indicate 'poor fen,' a class that is not used here (see page 107).					
OPEN SPHAGNUM BOG					
SPHAGNUM FUSCUM					
Sphagnum fuscum ^{80} - *Spagnum* spp. ^{6} - *Picea mariana* ^{5} - *Cladina* spp. ^{4}	10	3.2	4.0	429	2E
Sphagnum fuscum ^{45} - *Cladina rangiferina* ^{20} (Cowell *et al.* 1978)	7	-	2.3 (ice lens 42cm)	Kinoje	2E
SPHAGNUM MAGELLANICUM					
Sphagnum magellanicum ^{55} – *S. rubellum* ^{30} (Cowell *et al.* 1978)	0	-	2.1	Kinoje (ice lens 90cm)	2E
SPHAGNUM NEMOREUM					
Sphagnum nemoreum ^{75} - *Sphagnum* spp. ^{20} - *Carex oligosperma* ^{4} - *Scheuchzeria palustris* ^{3}	10	3.0	3.7	520	2E
Sphagnum nemoreum ^{75} - *Cladopodiella fluitans* ^{25} - *Carex limosa* ^{3}	2	3.2	5.0	449B	2E
OPEN POOL BOG					
CLADOPODIELLA FLUITANS					
Cladopodiella fluitans ^{55} - *Sphagnum nemoreum* ^{45} - *Carex limosa* ^{15} - *Rhynchospora alba* ^{5}	-5	4.9	>3.9	516	2E
Cladopodiella fluitans ^{80} - (open water ^{20})	-10	3.3	2.9 (5cm ice lens at 40cm)	565	2E
SPHAGNUM MAGELLANICUM - CAREX OLIGOSPERMA					
Sphagnum magellanicum ^{75} - *Carex oligosperma* ^{40} - *Sphagnum squarrosum* ^{20}	-5	4.2	1.7	434A	2E
SPHAGNUM LINDBERGII					
Sphagnum lindbergii ^{80} - *Carex oligosperma* ^{30} - *Cladopodiella fluitans* ^{20} - *Scirpus cespitosus* ^{17}	0	4.4	>2.0	Aquatuk	1E
SPHAGNUM MAJUS					
Sphagnum majus ^{20} - *Rhynchospora alba* ^{15} - *Utricularia cornuta* ^{15} - *Sphagnum nemoreum* ^{10}	-2	4.8	-	389	2E
Sphagnum majus ^{90} - *Scheuchzeria palustris* ^{10}	-7	4.1	>3.9	486A	2E
Sphagnum majus ^{70} - *Carex limosa* ^{3}	-5	5.1	3.2	449A	2E
Sphagnum majus ^{90} - *Carex oligosperma* ^{15}	-5	4.7	1.5	378C	1E

FORMATION ***PHYSIOGNOMIC GROUP*** DOMINANCE TYPE Site Type (% cover, ranges and means)	**Depth-to-water** range (mean) (cm)	**pH**	**Peat depth** range (mean) (m)	**Sample sites** Fig. 6 except as indicated	**Ecoregion**
FEN					
TREED					
TREED SHRUB-RICH FEN					
LARIX LARICINA - BETULA PUMILA					
Pleurozium schreberi ^{65} - *Sphagnum russowii* ^{20} - *Larix laricina* ^{10} - *Betula pumila* ^{10} - *Ledum groenlandicum* ^{10} - *Carex aquatilis* ^{5}	12	5.5	1.2	312B	0E
Sphagnum fallax ^{60} - *Larix laricina* ^{35} - *Aulocomnium palustre* ^{30} - *Betula pumila* ^{25} - *Equisetum fluviatile* ^{25}	12	5.4	2.7	541A	2E
LARIX LARICINA - BETULA PUMILA - CHAMAEDAPHNE CALYCULATA					
Composite: *Sphagnum* spp. $^{80-(90)-95)}$ - non-*Sphagnum* mosses $^{5-(10)-20}$ - *Larix laricina* $^{10-(17)-30}$ - *Betula pumila* $^{6-(14)-25}$ - *Salix* spp. $^{1-(9)-25}$)	5-(17)-25	4.8-(5.4)-5.9	1.5-(2.4)-3.0	(as follows)	1E, 2E
Sphagnum warnstorfii ^{80} - *Betula pumila* ^{25} - *Bryum pseudotriquetrum* ^{20} - *Menyanthes trifoliata* ^{15} - *Larix laricina* ^{10} - *Chamaedaphne calyculata* ^{10} - *Carex limosa* ^{8}	5	5.9	3.0	295B	1E
Sphagnum fallax ^{65} - *Sphagnum magellanicum* ^{30} - *Larix laricina* ^{30} - *Salix pedicellaris* ^{25} - *Chamaedaphne calyculata* ^{20} - *Betula pumila* ^{12}	25	5.5	1.5	550	2E
Sphagnum majus ^{70} - *Sphagnum fuscum* ^{15} - *Larix laricina* ^{10} - *Sphagnum magellanicum* ^{8} - *Chamaedaphne calyculata* ^{7} - *Betula pumila* ^{6} - *Drepanocladus exannulatus* ^{5}	20	4.8	2.7	444	2E
TREED LOWSHRUB FEN					
LARIX LARICINA - ANDROMEDA GLAUCOPHYLLA					
Composite: *Sphagnum* spp. $^{15-(50)-83}$ - non-*Sphagnum* mosses $^{1-(28)-65}$ - *Andromeda glaucophylla* $^{10-(23)-30}$ - *Larix laricina* $^{10-(19)-35}$ - *Chamaedaphne calyculata* $^{1-(12)-25}$ - *Betula pumila* $^{4-(5)-5)}$	10-(13)-15	5.1-(5.3)-5.6	2.5-(3.0)-3.3	(as follows)	2E
Campylium stellatum ^{60} - *Larix laricina* ^{35} - *Pleurozium schreberi* ^{20} - *Sphagnum warnstorfii* ^{15} - *Andromeda glaucophylla* ^{10} - *Chamaedaphne calyculata* ^{9}	15	5.6	2.5	560A	2E
Sphagnum fuscum ^{50} - *S. warnstorfii* ^{30} - *Andromeda glaucophylla* ^{30} - *Chamaedaphne calyculata* ^{25} - *Larix laricina* ^{12}	10	5.1	3.3	433	2E
Sphagnum fallax ^{50} - *S. magellanicum* ^{30} - *Andromeda glaucophylla* ^{30} - *Drepanocladus exannulatus* ^{17} - *Larix laricina* ^{10}	15	5.3	3.1	462A	2E
LARIX LARICINA - BETULA PUMILA					
Composite: *Sphagnum* spp. $^{10-(50)-100}$ - non-*Sphagnum* mosses $^{0-(46)-80}$ - *Larix laricina* $^{12-(19)-33}$ - *Betula pumila* $^{8-(17)-35}$ - *Chamaedaphne calyculata* $^{0-(6)-20}$ - *Carex limosa* $^{0-(6)-10)}$	5-(14)-22	4.8-(5.3)-5.9	1.5-(2.3)-2.9	(as follows)	1E, 2E
Sphagnum warnstorfii ^{47,80,90} - *Larix laricina* ^{11,20,33} - *Betula pumila* ^{12,13,20} (*Campylium stellatum* ^{0,5,40}, *Drepanocladus exannulatus* ^{0,0,15}, *Sphagnum magellanicum* ^{0,0,10})	17,17,20	5.0,5.4,5.5	0.6,2.1,2.9	554A,557A,822	2E

FORMATION *PHYSIOGNOMIC GROUP* DOMINANCE TYPE Site Type (% cover, ranges and means)	**Depth-to-water** range (mean) (cm)	**pH**	**Peat depth** range (mean) (m)	**Sample sites** Fig. 6 except as indicated	**Ecoregion**
Drepanocladus exannulatus 36 - *Sphagnum fallax* 35 - *Larix laricina* 17 -*Sphagnum fuscum* 10 - *Chamaedaphne calyculata* 10 - *Betula pumila* 8	17	5.0	1.5	573A	2E
Sphagnum fallax 90 - *Betula pumila* 15 - *Larix laricina* 12 - *S. magellanicum* 10 - *Carex limosa* 9	7	5.2	2.6	532B	2E
Tomenthypnum nitens 65 - *Sphagnum fallax* 25 - *Larix laricina* 25 -*Betula pumila* 20	5	5.9	1.9	371A	1E
Scorpidium scorpioides 80 - *Larix laricina* 20 - *Betula pumila* 10 - *Sphagnum fuscum* 10 - *Carex limosa* 10	2.	5.8	2.4	297B	1E
Sphagnum subsecundum 40 - *S. centrale* 30 - *Larix laricina* 20 - *Betula pumila* 20 - *Chamaedaphne calyculata* 20 - *Carex limosa* 10	17	4.8	2.1	506	2E
Sphagnum lindbergii 48 - *Drepanocladus fluitans* 30 - *Larix laricina* 15 - *Betula pumila* 10 - *Carex limosa* 10	22	4.9	2.5	564A	2E
Campylium stellatum 60 - *Carex lasiocarpa* 40 - *Cladopodiella fluitans* 20 - *Betula pumila* 20 - *Larix laricina* 15 - *Chamaedaphne calyculata* 15	20	5.2	2.7	498A	2E
Tomenthypnum nitens 80 - *Betula pumila* 35 - *Menyanthes trifoliata* 35 - *Larix laricina* 15 - *Carex limosa* 10 - *Sphagnum subsecundum* 10	15	5.9	2.5	500B	2E
Note: Some paludified TREED LOWSHRUB FENS are transitional to BOG: for example,					
Sphagnum obtusum 100 - *Larix laricina* 10 - *Betula pumila* 5 - *Carex aquatilis* 5 - *Carex magellanica* 5	0	5.2	1.6	308B	0E
LARIX LARICINA - CHAMAEDAPHNE CALYCULATA					
Larix laricina 13 - *Chamaedaphne calyculata* 14 - *Sphagnum warnstorfii* 12 - *Carex limosa* 11 - *Betula pumila* 9 (average, n = 5; Jeglum and Cowell 1982)	18	5.9	1.3	Kinoje	2E
LARIX LARICINA - SALIX CANDIDA					
Larix laricina - *Salix candida* - *Betula pumila* - *Carex aquatilis*	-	-	1.0	Fort Severn	0E
THUJA OCCIDENTALIS - LARIX LARICINA - BETULA PUMILA					
Sphagnum rubellum 70 - *Thuja occidentalis* 40 - *S. centrale* 10 - *Larix laricina* 9 - *Betula pumila* 8	30	5.3	1.3	563B	2E
THUJA OCCIDENTALIS - MYRICA GALE					
Sphagnum warnstorfii 40 - *S. magellanicum* 40 - *Myrica gale* 35 - *Thuja occidentalis* 20 (Cowell et *al.* 1978)	6	-	1.1	Kinoje	2E
Thuja occidentalis 26 - *Sphagnum magellanicum* 24 - *Myrica gale* 17 - *S russowii* 16 - *Chamaedaphne calyculata* 9 (average, n = 4; Jeglum and Cowell 1982)	18	5.9	1.3	Kinoje	2E
TREED GRAMINOID FEN					
LARIX LARICINA - CAREX CHORDORRHIZA - CAREX LIMOSA					
Sphagnum fallax 70 - *Carex chordorrhiza* 20 - *C. limosa* 15 - *Sphagnum magellanicum* 15 - *Drepanocladus exannulatus* 10 - *Larix laricina* 10	17	5.0	2.4	477A	2E

FORMATION *PHYSIOGNOMIC GROUP* DOMINANCE TYPE Site Type (% cover, ranges and means)	Depth-to-water range (mean) (cm)	pH	Peat depth range (mean) (m)	Sample sites Fig. 6 except as indicated	Ecoregion
LARIX LARICINA - CAREX LASIOCARPA					
Sphagnum fallax 30 - *Scorpidium scorpioides* 25 - *Campylium stellatum* 25 - *Sphagnum warnstorfii* 15 - *Carex lasiocarpa* 10 - *Larix laricina* 10 - *Scirpus cespitosus* 5	15	5.3	1.8	391A	2E
LARIX LARICINA - CAREX LIMOSA - SCIRPUS HUDSONIANUS					
Sphagnum rubellum 30 - *S. magellanicum* 30 - *S. fuscum* 20 - *Larix laricina* 15 - *Campylium stellatum* 10 - *Tomenthypnum falcifolium* 10 - *Carex limosa* 5 - *Scirpus hudsonianus* 5	20	5.5	3.8	490B	2E
*Tomenthypnum nitens*60 – *Scorpidium scorpioides*40 - *Larix laricina* 12 - *Scirpus hudsonianus* 10 - *Carex limosa* 10 - *Carex chordorrhiza* 5 - *Andromeda polifolia* 5	2	6.5	2.2	361	1E
THUJA OCCIDENTALIS - SCIRPUS HUDSONIAUS - SCIRPUS CESPITOSUS					
Campylium stellatum 80 - *Thuja occidentalis* 10 - *Scirpus hudsonianus* 8 - *Scirpus cespitosus* 6 - *Sphagnum warnstorfii* 6 - *Carex sterilis* 5	7	6.2	1.8	456	2E
FEN					
OPEN					
OPEN SHRUB-RICH FEN					
LARIX LARICINA (shrub) - BETULA PUMILA					
Tomenthypnum nitens 60 - *Sphagnum fallax* 15 - *S. nemoreum* 10 - *Larix laricina* 10 - *Betula pumila*10 - *Equisetum fluviatile*5	15	5.7	1.0	372A	1E
SALIX PEDICELLARIS					
Salix pedicellaris 40 - *Betula pumila* 35 - *Vaccinium uliginosum* 10 - *Campylium stellatum* 10 - *Pseudobryum cinclidoides* 10	-5	5.4	2.1	298A	1E
OPEN LOWSHRUB FEN					
ANDROMEDA GLAUCOPHYLLA					
Sphagnum obtusum 90 - *Andromeda glaucophylla* 30 - *Calliergon stramineum* 10 - *Carex limosa* 5	2	5.1	2.2	497B	2E
BETULA PUMILA					
Tomenthypnum nitens 70 - *Scirpus hudsonianus* 50 - *Drepanocladus revolvens* 15 - *Betula pumila* 10 - *Larix laricina* 5	2	6.1	1.3	422	2E
Betula pumila - Larix laricina (shrub) - Carex aquatilis -	-	-	-	Fort Severn	0E
Sphagnum magellanicum 70 - *Betula pumila* 15 - *S. subsecundum* 10 - *Andromeda glaucophylla* 10 - *Chamaedaphne calyculata* 9	15	5.2	1.8	468	2E
Sphagnum fallax 80 - *Drepanocladus fluitans* 15 - *Larix laricina* 10 - *Betula pumila* 8 - *Carex chordorrhiza* 7	12	4.9	>3.0	424	2E
CHAMAEDAPHNE CALYCULATA					
Drepanocladus exannulatus 51,70 - *Chamaedaphne calyculata* 10,40 - *Sphagnum* spp. 25,30 - *Larix laricina* 10,13	10,12	5.0,5.4	1.3,2.0	394,379	2E
Tomenthypnum nitens 45 - *Sphagnum fuscum* 35 - *S. warnstorfii* 15 - *Chamaedaphne calyculata*10 - *Betula pumila* 8 - *Larix laricina* 5 - *Picea mariana* 6	35	5.4	1.4	396A	2E

FORMATION *PHYSIOGNOMIC GROUP* DOMINANCE TYPE Site Type (% cover, ranges and means)	**Depth-to-water** range (mean) (cm)	**pH**	**Peat depth** range (mean) (m)	**Sample sites** Fig. 6 except as indicated	**Ecoregion**
LARIX LARICINA (shrub) - BETULA PUMILA					
Scorpidium scorpioides ^{80} - *Scirpus cespitosus* ^{40} - *Larix laricina* ^{10} (- *Betula pumila* $^{1\text{-}5}$)	0	6.2	1.0	273	0E
Paludella squarrosa ^{60} - *Tomenthypnum nitens* ^{20} - *Carex aquatilis* ^{15} - *Larix laricina* ^{10} - *Betula pumila* ^{5}	15	5.7	(active layer 35cm)	283A	0E
MYRICA GALE					
Campylium stellatum ^{30} - *Myrica gale* ^{30} - *Carex limosa* ^{20} - *Scorpidium scorpioides* ^{20} - *Potentilla fruticosa* ^{15} - *C. lasiocarpa* ^{10}	15	5.2	1.1	563A	2E
Campylium stellatum ^{10} - *Myrica gale* ^{10} – *Betula pumila* ^{6} - *Potentilla fruticosa* ^{5} - *C. lasiocarpa* ^{15}	18	5.4	1.8	821	2E
Sphagnum teres ^{14} - *Campylium stellatum* ^{13} - *Carex limosa* ^{13} - *Myrica gale* ^{10} - *Menyanthes trifoliata* ^{10} - *Potentilla fruticosa* ^{6} - *Andromeda glaucophylla* ^{5} (average of n = 7; Jeglum and Cowell 1982)	14	5.2	1.1	Kinoje	2E
POTENTILLA FRUTICOSA					
Campylium stellatum ^{40} - *Sphagnum fallax* ^{40} - *Scirpus cespitosus* ^{20} - *Potentilla fruticosa* ^{15} – *Sphagnum warnstorfii* ^{10}	17	5.5	0.7	464	2E
Campylium stellatum ^{15} - *Potentilla fruticosa* ^{20} - *Betula pumila* ^{10} - *Carex lasiocarpa* ^{8} - *Larix laricina* ^{8} - *Scirpus cespitosus* ^{5} - *Myrica gale* ^{4}	12	5.5	1.0	819, Kinoje	2E
OPEN DWARF-SHRUB FEN					
Note: Northern sites with >30cm peat are part of tundra wetland series; see also site types under FRESHWATER DWARF-SHRUB MEADOW MARSH, below.					
ARCTOSTAPHYLOS ALPINA					
Arctostaphylos alpina ^{17} - *Salix myrtillifolia* ^{7} - *S. lanata* ^{7} - *Vaccinium uliginosum* ^{6} - *Hedysarum alpinum* ^{5} - *Dryas integrifolia* ^{4} - *Solidago multiradiata* ^{4} (riparian)	-	-	-	Shagamu	0E
VACCINIUM ULIGINOSUM					
Tomenthypnum nitens ^{52} - *Drepanocladus vernicosus* ^{18} - *Vaccinium uliginosum* ^{16} - *Salix reticulata* ^{12} - *S. planifolia* ^{10} - *Bartsia alpina* ^{7} - *Equisetum arvense* ^{6}	5	6.0	(active layer 30cm)	227F	0E
Aulocomnium palustre ^{42} - *Dicranum undulatum* ^{18} - *Vaccinium uliginosum* ^{14} - *Hylocomnium splendens* ^{12} - *Salix planifolia* ^{10} - *Betula glandulosa* ^{6} - *Empetrum nigrum* ^{6} - *Arctostaphylos alpina* ^{6} (see also Kershaw 1974, series E, F)	5	5.9	(active layer 30cm)	227C	0E
OPEN GRAMINOID FEN					
CAREX AQUATILIS					
Drepanocladus spp. ^{95,100} - *Carex aquatilis* ^{5,15} - *Betula pumila* ^{1,10} (See also Kershaw 1974, series A)	5,7	6.0,6.2	(35,40cm active layers)	267,322B	0E
Aulocomnium palustre ^{30,70} - *Carex aquatilis* ^{15,20} - *Tomenthypnum niten* ^{1,60} - *Carex* spp. ^{6,11}	0,5	5.8,6.5	0.6,1.6	308A,329B	0E
Aulocomnium turgidum ^{20} - *Carex aquatilis* ^{5} - *C. capillaris* ^{5} - *Tomenthypnum nitens* ^{5}	20	7.0	(55cm active layer)	268B	0E
Scorpidium scorpioides ^{100} - *Carex aquatilis* ^{45}	7	6.6	0.4	325	0E
Note: This Dominance Type includes unpatterned permafrost (tundra) fen plains, or OPEN GRAMINOID PEAT PLATEAU (see above); such as...					
Scorpidium turgescens ^{95} - Carex aquatilis ^{15} - C. limosa ^{10}	10	5.8	(active layer 35cm	828	0E

FORMATION ***PHYSIOGNOMIC GROUP*** DOMINANCE TYPE Site Type (% cover, ranges and means)	**Depth-to-water** range (mean) (cm)	**pH**	**Peat depth** range (mean) (m)	**Sample sites** Fig. 6 except as indicated	**Ecoregion**
CAREX CHORDORRHIZA					
Campylium stellatum $^{20\text{-}(65)\text{-}100}$ - *Carex chordorrhiza* $^{10\text{-}(18)\text{-}20}$ - *Scorpidium scorpioides* $^{0\text{-}(14)\text{-}30}$ - *Carex limosa* $^{1\text{-}(5)\text{-}7}$	2-(5)-10	5.6-(6.1)-6.6	0.8-(1.1)-1.3	370 395,396B,574	1E 2E
Scorpidium scorpioides ^{107} - *Carex chordorrhiza* ^{30} - *C. aquatilis* ^{15} - *C. limosa* ^{10}	10	6.3	0.6	323	0E
Scorpidium scorpioides ^{94} - *Carex chordorrhiza* ^{6} - *C. livida* ^{4} - *C. limosa* ^{3}	8	5.4	1.8	821	2E
Drepanocladus aduncus ^{60} - *Sphagnum obtusum* ^{40} - *Carex chordorrhiza* ^{20} - *Calamagrostis stricta* ^{15} - *Carex diandra* ^{10}	0	5.8	(active layer to 45cm)	277	1E
Drepanocladus vernicosus ^{60} - *Aulocomnium palustre* ^{15} - *Carex chordorrhiza* ^{10} - *Cinclidium stygium* ^{10}	20	5.4	1.1	392	2E
CAREX EXILIS					
Tomenthypnum nitens ^{30} - *Scorpidium scorpioides* ^{20} - *Carex exilis* ^{10} - *Potentilla fruticosa* ^{5}	0	5.9	2.9	431	2E
Campylium stellatum ^{50} - *Carex exilis* ^{45} - *Scorpidium scorpioides* ^{30} - *Scirpus cespitosus* ^{5}	0	5.5	1.7	441	2E
CAREX LASIOCARPA					
Campylium stellatum $^{10\text{-}(34)\text{-}50}$ - *Carex lasiocarpa* $^{12\text{-}(41)\text{-}80}$ - *Scorpidium scorpioides* $^{0\text{-}(22)\text{-}40}$ - *Carex limosa* $^{0\text{-}(5)\text{-}10}$	0-(8)-15	5.5-(5.8)-6.1	0.6-(1.0)-1.3	4,5A,575	2E
Campylium stellatum ^{10} - *Carex lasiocarpa* ^{25} - *Myrica gale* ^{8} - *Potentilla fruticosa* ^{12} - *Menyanthes trifoliata* ^{5}	12	5.5	1.0	819	2E
Sphagnum subsecundum ^{15,60} - *Carex lasiocarpa* ^{20,70} - *(S. warnstorfii - Campylium stellatum - Rhynchospora alba)*	5,10	5.2,5.4	1.6,2.4	562A,477B	2E
Drepanocladus revolvens ^{40} - *Scorpidium scorpioides* ^{30} - *Carex lasiocarpa* ^{18} - *Potentilla fruticosa* ^{15} - *Scirpus cespitosus* ^{10}	17	5.9	1.2	549	2E
CAREX LIMOSA					
Scorpidium scorpioides ^{80} - *Carex limosa* ^{50} - *C. rostrata* (s.s.) ^{20}	5	5.8	(32cm active layer)	270A	0E
Scorpidium scorpioides ^{100} - *Carex limosa* ^{15} - *C. diandra* ^{10} - *Betula pumila* ^{5} - *Salix* spp. ^{5}	2	5.7	0.5	311	0E
Scorpidium scorpioides $^{40\text{-}(77)\text{-}100}$ - *Carex limosa* $^{10\text{-}(23)\text{-}45}$ - *C. chordorrhiza* $^{0\text{-}(7)\text{-}30}$ - *Menyanthes trifoliata* $^{1\text{-}(5)\text{-}20}$ - (*Scirpus* spp. $^{0\text{-}10}$ - *Tomenthypnum nitens* $^{0\text{-}25}$)	-10-(-1)-2	5.6-(6.0)-6.6	1.3-(2.1)-2.8 (active layers at two sites 54 & 70cm)	270B,312A,322A 292A,295A,300C, 605 5B,500A,548B	0E 1E 2E
Scorpidium scorpioides ^{12} - *Carex limosa* ^{11} - *Menyanthes trifoliata* ^{8} (average, n = 9; Jeglum and Cowell 1982)	-1	5.5	1.7	Kinoje	2E
Sphagnum majus ^{90} - *Menyanthes trifoliata* ^{30} - *Carex limosa* ^{15} - *Drepanocladus exannulatus* ^{10}	5	5.1	2.2	497A	2E
Campylium stellatum $^{60\text{-}(76)\text{-}95}$ - *Scorpidium scorpioides* $^{0\text{-}(22)\text{-}40}$ - *Carex limosa* $^{5\text{-}(15)\text{-}30}$	-2-(6)-15	5.5-(5.8)-6.0	1.6-(1.9)-2.5	297 2,560B	0E 2E
Drepanocladus exannulatus ^{80} - *Carex limosa* ^{20} - *Mylia anomala* ^{15}	0	5.2	(active layer 65cm)	831B	1
Scorpidium scorpioides ^{80} - *Carex limosa* ^{15} - *Scirpus cespitosus* ^{8}	5	-	(55cm active layer)	824	1E
CAREX LIVIDA					
Cladopodiella fluitans ^{60} - *Carex livida* ^{33} - *C. chordorrhiza* ^{17} - *C. limosa* ^{5}	10	5.8	1.0	372B	1E
Campylium stellatum ^{65} - *Carex livida* ^{10} - *C. limosa* ^{10} - *Menyanthes trifoliata* ^{8}	10	5.8	1.0	372B	1E

FORMATION *PHYSIOGNOMIC GROUP* DOMINANCE TYPE Site Type (% cover, ranges and means)	**Depth-to-water** range (mean) (cm)	**pH**	**Peat depth** range (mean) (m)	**Sample sites** Fig. 6 except as indicated	**Ecoregion**
CAREX SAXATILIS					
Carex saxatilis - Equisetum variegatum - Drepanocladus spp. - *Campylium stellatum* (Kershaw 1974, series B,C)	-	-	-	Pen Islands	0E
CAREX UTRICULATA					
Sphagnum majus 60 - *Drepanocladus exannulatus* 40 - *Carex utriculata* 30 - *C. limosa* 4	2	4.9	1.7	571B	2E
SCIRPUS CESPITOSUS					
Scorpidium scorpioides 30-(66)-95 - *Scirpus cespitosus* 10-(27)-60 - *Carex limosa* 0-(7)-15 - *C. livida* 0-(3)-10 - *Menyanthes trifoliata* 0-(3)-5 - (-*Sphagnum warnstorfii* 0-10)	-2-(2)-5	5.1-(5.7)-6.5	0.9-(1.8)-2.3 (3 sites with active layers 35, 35 & 50cm)	268A,269,283B 299A,287,304B, 437A,452A,570A	0E 1E 2E
Scorpidium scorpioides 80 - *Scirpus cespitosus* 16 - *Carex limosa* 9 - *Rhynchospora alba* 5 - *Campylium stellatum* 10	5	5.3	0.6	822	2E
Campylium stellatum 30-(53)-90 - *Scirpus cespitosus* 15-(38)-65 - *Scorpidium scorpioides* 0-(13)-30 (-*Drepanocladus revolvens* 0-40 - *Carex limosa* 0-15 - *C. chordorniza* 0-20 - *Menyanthes trifoliata* 0-7)	-5-(3)-7	5.4-(6.0)-6.7	0.7-(1.3)-3.3 (1 site with 60cm active layer)	316,321 367A,596, 438,450,526, 554B,596	0E 1E 2E
(*Algal marl* 25-(45)-80) - *Scirpus cespitosus* 20-(27)-40 - *Scorpidium scorpioides* 0-(9)-15 - *Carex livida* 1-(7)-10 - *C. limosa* 0-(5)-10	0-(3)-7	5.9-(6.3)-6.7	0.4-(0.9)->2.0	275,329A 7,11,291	0E 1E
Rhacomitrium lanuginosum 60 - *Scirpus cespitosus* 11 - *Carex limosa* 0-(7)-15 - *C. chordorrhiza* 7- *Scorpidium scorpioides* 5	5	6.5	(active layer to 60cm)	324	0E
Tomenthypnum nitens 60,90 - *Scirpus cespitusus* 15,25 - *Scorpidium scorpioides* 10,15	2,7	6.2,6,8	0.5,1.0	362,363	1E
Drepanocladus revolvens 60,90 - *Scirpus cespitosus* 25,50 - *Carex lasiocarpa* 10,20 - *Scorpidium scorpioides* 5,10 - *Potentilla fruticosa* 5,8	0,10	6.4,6.4	2.0,2.0	7,546	1E,2E
Scirpus cespitosus 70 - *Carex exilis* 20 - *Sphagnum warnstorfii* 15 - *Sphagnum* spp. 11	7	5.4	>3.9	469A	2E
Scirpus cespitosus 65 - *Sphagnum fuscum* 30 - *Campylium stellatum* 10 - *Potentilla fruticosa* 7 - *Carex exilis* 6	17	5.3	2.5	544	2E
Sphagnum lenense 40 - *Mylia anomala* 20 - *Scirpus cespitosus* 20	2	-	(active layer to 100cm)	831C	0E
SCIRPUS HUDSONIANUS					
Scorpidium scorpioides 100 - *Scirpus hudsonianus* 22 - *Equisetum fluviatile* 22 - *Carex limosa* 5	5	6.0	1.4	358	1E
Drepanocladus revolvens 60 - *Campylium stellatum* 30 - *Scirpus hudsonianus* 20 - *Andromeda polifolia* 10	5	5.9	2.0	371B	1E
OPEN POOL FEN					
ERIOPHORUM CHAMISSONIS					
(Open water and mud 95) - *Eriophorum chamissonis* 10 - *Scirpus cespitosus* 5 - *Carex limosa* 8	-5	6.0	>1.5 (ice lens 55cm)	10	0E
CAREX LIMOSA					
(Open water 80-(85)-100) - *Carex limosa* 10-(13)-20 (*Sphagnum squarrosum, Scorpidium scorpioides, Utricularia intermedia, Scirpus hudsonianus, Carex chordorrhiza)*	-10-(-12)-17	5.1-(5.7)-6.2	1.0-(2.2)->3.0 (one site with active layer 1m)	274A,319B 427B,462B	1E 2E

FORMATION ***PHYSIOGNOMIC GROUP*** DOMINANCE TYPE Site Type (% cover, ranges and means)	**Depth-to-water** range (mean) (cm)	**pH**	**Peat depth** range (mean) (m)	**Sample sites** Fig. 6 except as indicated	**Ecoregion**
(Open water 40) - *Drepanocladus exannulatus* 100 - *Carex limosa* 50 - Menyanthes trifoliata 10	-5	5.6	(active layer 32cm)	278C	0E
(Open water 85) - *Carex limosa* 25 - *Sphagnum warnstorfii* 15 - *Scirpus hudsonianus* 10	-5	5.8	1.9	498B	2E
MENYANTHES TRIFOLIATA					
(Open water 90-(93)-100) - *Menyanthes trifoliata* 7-(16)-20 - (*Scorpidium scorpioides* - *Carex chordorrhiza* - *C. limosa*)	-15-(-22)-30	5.2-(5.8)-6.3	0.9-(2.6)->3.9	460B,469B, 562B,570B	2E
(Open water 20) - *Cladopodiella fluitans* 60 - *Sphagnum magellanicum* 20 - *Menyanthes trifoliata* 20 - *Scheuchzeria palustris* 15	-17	5.1	3.5	508A	2E
(Open water 0-(13)-20) - *Drepanocladus exannulatus* 60-(77)-90 - *Menyanthes trifoliata* 5-(13)-20 - *Carex limosa* 6-(9)-10 - *Scheuchzeria palustris* 1-(7)-15	-2-(-5)-10	5.3-(5.3)-5.4	2.6-(3.0)-3.5	440C,476A,557B	2E
Note: Same site type noted by Cowell *et al.* 1978	-	-	2.3 (ice lens 55cm)	Kinoje	2E
RHYNCHOSPORA ALBA					
Gymnocolea inflata 60 - *Sphagnum lenense* 15 - *Rhynchospora alba* 5	10	5.2	-	Kinoje	2E
SCHEUCHZERIA PALUSTRIS					
(Open water 80) - *Scorpidium scorpioides* 15 - *Scheuchzeria palustris* 10 - *Carex chordorrhiza* 8	-22	5.6	>3.9	490A	2E
SCORPIDIUM SCORPIOIDES					
Scorpidium scorpioides 100 (Cowell *et al.* 1978)	18 (rising palsa)	-	2.7 (ice lens 35cm)	Kinoje	2E
(Black detritus 50-60) - *Scorpidium scorpioides* 35-50 - *Menyanthes trifoliata* 3-5 - *Scirpus cespitosus* 1-2 - *Carex limosa* 0-5	0-5	5.2-5.3	0.6->1.0	822,Kinoje	2E
(Open water 30) - *Scorpidium scorpioides* 80 - *Menyanthes trifoliata* 4 - *Carex livida* 3	0	5.6	1.8	821	2E
(Water - black detritus 5 0-(60)-80) - *Scorpidium scorpioides* 20-(35)-45 - *Scirpus hudsonianus* (12) - *S. cespitosus* (2)	0	5.2	-	Kinoje	2E
Scorpidium scorpioides 40 - *Drepanocladus exannulatus* 24 - *Sphagnum tenellum* 14 - *Carex limosa* 11 - *Menyanthes trifoliata* 9 (averages, n = 6; Jeglum and Cowell 1982)	5	5.4	1.7	Kinoje	2E
SWAMP					
CONIFER SWAMP					
LARIX LARICINA					
Larix laricina 60 - *Pleurozium schreberi* 50 - *Hylocomnium splendens* 20 - *Sphagnum warnstorfii* 20 - *Menyanthes trifoliata* 15 - *Carex chordorrhiza* 10	20	5.8	2.8	548A	2E
PICEA MARIANA - LEDUM GROENLANDICUM					
Cladina rangiferina 80 - *Ledum groenlandicum* 50 - *Picea mariana* 23 - *Pleurozium schreberi* 20 - *Alnus crispa* 5	Unsaturated	Unsaturated	0.3	Sturgeon Lake	1E
Note: Similar site type, Cowell *et al.* 1978	17	-	1.5 (ice lenses 35cm)	Kinoje	2E

FORMATION ***PHYSIOGNOMIC GROUP*** DOMINANCE TYPE Site Type (% cover, ranges and means)	**Depth-to-water** range (mean) (cm)	**pH**	**Peat depth** range (mean) (m)	**Sample sites** Fig. 6 except as indicated	**Ecoregion**
Picea mariana [31] - *Pleurozium schreberi* [20] - *Alnus rugosa* [18] - *Ledum groenlandicum* [14] (average, n = 5; Jeglum and Cowell 1982)	28	5.5	1.2	Kinoje	2E
Cladina rangiferina [55] - *Picea mariana* [40] - *Ledum groenlandicum* [30] - *Sphagnum fuscum* [15] - *Cladina alpestris* [15]	60	3.3	1.7	571C	2E
Cladina spp. - *Ledum groenlandicum* - *Sphagnum fuscum* - *Picea mariana* - *Cornus canadensis* - *Vaccinium myrtilloides*	Unsaturated	Unsaturated	0.5	Aquatuk	1E
Sphagnum fuscum - *Picea mariana* - *Ledum groenlandicum* - *Cornus canadensis*	-	-	-	422	2E
PICEA GLAUCA - ABIES BALSAMEA					
Picea glauca [34] - *Abies balsamea* [27] (Cowell *et al.* 1978)	4	-	0.2-0.5 (ice lens 50cm)	Kinoje	2E
THUJA OCCIDENTALIS	-	-	-	Kenogami basin	2E
BROADLEAF SWAMP					
POPULUS BALSAMIFERA					
Campylium hispidulum [60] - *Alnus crispa* [25] - *Populus balsamifera* [15] - *Calamagrostis canadensis* [30] - *Carex aquatilis* [10] - *Salix planifolia* [10]	-	-	0.15	Aquatuk	1E
Populus balsamifera - *Cornus stolonifera* - *Fraxinus nigra*	-	-	-	Long Rapids	2E
ULMUS AMERICANA - FRAXINUS NIGRA					
Ulmus americana - *Populus balsamifera* - *Fraxinus nigra* - *Matteuccia struthiopteris*	-	-	0	Kenogami River, Pagwa River	2E
THICKET SWAMP					
ALNUS CRISPA					
Campylium hispidulum [85] - *Alnus crispa* [25] - *Salix planifolia* [20] - *Myrica gale* [13] - *Betula pumila* [15] - *Rhamnus alnifolius* [8] - *Potentilla fruticosa* [7] (lakeshore)	-	-	0.1	Aquatuk	1E
Campylium hispidulum [50] - *Alnus crispa* [80] - *Salix planifolia* [10] - *Equisetum arvense* [2]	-	-	-	Aquatuk	1E
ALNUS RUGOSA					
Alnus rugosa [25] - *Rhamnus alnifolius* [30] - *Viburnum edule* [20] - *Salix bebbiana* [10] - *Cornus stolonifera* [5]	-	-	30cm peat and gravel over ice	274	1E
Alnus rugosa [30] - *Glyceria grandis* [12] - *Anemone canadensis* [11] - *Agrostis gigantea* [7] - *Thalictrum venulosum* [6] (Riley and McKay 1980)	-	-	-	Shipsands	2E
Alnus rugosa [21] - *Cornus canadensis* [18] - *Betula pumila* [16] - *Salix planifolia* [15] (average, n = 2; Jeglum and Cowell 1982)	-1	6.0	1.8	Kinoje	2E
CORNUS STOLONIFERA					
Cornus stolonifera - *Salix exigua*	-	-	-	Long Rapids	2E
MYRICA GALE					
Myrica gale (Riley and McKay 1980)	-	-	-	SW James Bay	2E
SALIX CORDATA					
Salix cordata - *S. eriocephala* (*Potentilla anserina, P. fruticosa, Deschampsia cespitosa, Calamagrostis inexpansa, Thalictrum venulosum* var. *confine*)	-	-	-	Attawapiskat	2E

FORMATION ***PHYSIOGNOMIC GROUP*** DOMINANCE TYPE Site Type (% cover, ranges and means)	**Depth-to-water** range (mean) (cm)	**pH**	**Peat depth** range (mean) (m)	**Sample sites** Fig. 6 except as indicated	**Ecoregion**
SALIX EXIGUA					
Salix exigua - Salix lucida - Populus balsamifera - Thalictrum venulosum	-	-	-	Kenogami	2E
Salix exigua [16] *- Alnus rugosa* [12] *- Glyceria grandis* [12] *- Anemone canadensis* [6] *- Equisetum pratense* [5] *- Vicia cracca* [5] (Riley and McKay 1980)	-	-	-	Shipsands	2E
Salix exigua [20] *- Anemone canadensis* [17] *- Agrostis gigantea* [12] *- Petasites sagittatus* [12] *- Equisetum pratense* [12] *- Impatiens biflora* [11] *- Vicia cracca* [9] (Riley and McKay 1980)	-	-	-	Shipsands	2E
SALIX GLAUCA					
Salix glauca - Juncus balticus - Calamagrostis stricta - Lathyrus palustris (Riley and McKay 1980)	-	-	-	SW James Bay	2E
Salix glauca [26] *- S. myrtillifolia* [17] *- S. planifolia* [7] *- Potentilla fruticosa* [6]	-	-	Riparian, over ice	Shagamu	0E
SALIX PELLITA					
Salix pellita - Populus balsamifera - S. lucida	-	-	-	282	1E
Salix pellita - S. cordata	-	-	-	Attawapiskat	2E
SALIX PLANIFOLIA					
Salix planifolia - S. candida (Maycock 1979)				-	0E
Salix planifolia - Calamagrostis canadensis	-	-	-	Fort Severn	0E
Salix planifolia - Alnus rugosa - Calamagrostis canadensis - Carex aquatilis -	-	-	-	Kenogami River	2E
Salix planifolia - Alnus crispa – Betula pumila - S. pedicellaris	-	-	-	Attawapiskat	2E
SALIX SERISSIMA					
Salix serissima [12] *- Alnus rugosa* [11] *- Pyrola asarifolia* [8] *- Rubus acaulis* [8] *- Carex interior* [6] *- Equisetum pratense* [5] (Riley and McKay 1980)	-	-	-	Shipsands	2E
Salix serissima [14] *- Equisetum variegatum* [8] *- Alnus rugosa* [7] *- Juncus balticus* [7] *- Galium labradoricum* [7] (Riley and McKay 1980)	-	-	-	Shipsands	2E
MARSH					
FRESHWATER					
SHALLOW MARSH					
ARCTOPHILA FULVA					
Arctophila fulva - Hippuris vulgaris - Carex aquatilis - (with *Cardamine pratensis, Calamagrostis stricta, Epilobium leptophyllum*)	-	8.8 (conductivity 800 μmhos)	-	Shagamu	0E
CAREX AQUATILIS					
Carex aquatilis - Petasites sagittatus (with *Caltha palustris, Carex diandra, Potentilla palustris*)	-	-	-	Shagamu	0E
Carex aquatilis - C. chordorrhiza - Salix planifolia - Betula pumila - Eriophorum angustifolium (Maycock 1979)	-	-	-	-	0E
CAREX LASIOCARPA					
Carex lasiocarpa [15] - (open water [100])	-35	6.7	0.5	336	1E
CAREX LIMOSA					
Carex limosa - C. recta - C. aquatilis - C. diandra - C. saxatilis (Riley and McKay 1980)	-	-	-	SW James Bay	2E

FORMATION ***PHYSIOGNOMIC GROUP*** DOMINANCE TYPE Site Type (% cover, ranges and means)	**Depth-to-water** range (mean) (cm)	**pH**	**Peat depth** range (mean) (m)	**Sample sites** Fig. 6 except as indicated	**Ecoregion**
CAREX RECTA					
Carex recta - C. aquatilis - Geum rivale - Menyanthes trifoliata (Riley and McKay 1980)	-	-	-	SW James Bay	2E
CAREX RETRORSA					
Carex retrorsa - C. limosa - C. diandra (Riley and McKay 1980)	-	-	-	SW James Bay	2E
Carex retrorsa [35] - *C. oligosperma* [25] - *Sphagnum annulatum* [25]	-20	5.1	>1.2	425	2E
CAREX UTRICULATA					
Carex utriculata - C. aquatilis - Carex saxatilis	-	6.9	-	Shagamu	0E
Carex utriculata [45] - *C. aquatilis* [25] (Also Riley and McKay 1980)	-15	5.8	2.1	298B SW James Bay	1E 2E
Carex utriculata [45] - *Potentilla palustris* [20] (Cowell *et al.* 1978)	-8		1.7 (ice lens 65cm)	Kinoje	2E
Carex utriculata [33] - *Eleocharis smallii* [14] - *Potentilla palustris* [10] (averages, n = 2; Jeglum and Cowell 1982)	1	5.6	1.1	Kinoje	2E
ELEOCHARIS SMALLII					
Eleocharis smallii - E. acicularis - Carex rostrata s.s. - *C. aquatilis*	0 to -10	-	0	Aquatuk Kinoje	1E 2E
EQUISETUM FLUVIATILE					
Equisetum fluviatile - Menyanthes trifoliata - Myriophyllum sibiricum (Maycock 1979)	-	-	-		0E
Equisetum fluviatile - Carex diandra - Scorpidium scorpioides (*- Potentilla palustris*)	-	-	-	SW James Bay	2E
HIPPURIS VULGARIS					
Hippuris vulgaris	(up to)-30	-	-	Aquatuk	1E
Hippuris vulgaris - Potamogeton filiformis (Maycock 1979)	-	-	-	-	0E
MENYANTHES TRIFOLIATA					
Menyanthes trifoliata - Utricularia vulgaris - Carex aquatilis (Riley and McKay 1980)	-	-	-	SW James Bay	2E
Menyanthes trifoliata - Salix serissima - Carex lanuginosa - C. limosa (Riley and McKay 1980)	-	-	-	SW James Bay	2E
Menyanthes trifoliata - Carex aquatilis - Utricularia intermedia - Potentilla palustris (Maycock 1979)	-	-	-	-	0E
PETASITES SAGITTATUS					
Petasites sagittatus (with *Carex glareosa, Stellaria longifolia, Cardamine pratensis, Epilobium leptophyllum*	-	8.8 (conductivity 800 μmhos)	-	Shagamu	0E
PHRAGMITES AUSTRALIS					
Phragmites australis	-	-	-	Rogers Twp.	2E
POTENTILLA PALUSTRIS					
Potentilla palustris - Carex limosa (Riley and McKay 1980)	-	-	-	SW James Bay	2E
DEEP MARSH					
SCIRPUS ACUTUS					
Scirpus acutus [20] - *Carex aquatilis* [5]	-20->100	5.7	1.8	403B	2E
TYPHA LATIFOLIA					
Typha latifolia (with *Utricularia vulgaris, Carex aquatilis, C. retrorsa, Hippuris vulgaris, Lysimachia thyrsiflora, Geum rivale, Lemna trisulca*) (Riley and McKay 1980)	-	-	-	SW James Bay	2E

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MEADOW MARSH					
ALOPECURUS AEQUALIS					
Alopecurus aequalis - Glyceria borealis - Rorippa palustris - Ranunculus gmelinii (karst sinkhole)	-	-	-	Attawapiskat	2E
CALAMAGROSTIS CANADENSIS					
Calamagrostis canadensis - Potentilla palustris - Glyceria spp. - (drained beaver pond)	-	-	-	480	2E
Calliergon giganteum – Calamagrostis canadensis - Juncus filiformis – Carex utriculata (karst sinkhole)	-	6.8	-	Attawapiskat	2E
CALAMAGROSTIS STRICTA					
Campylium stellatum 90 - *Calamagrostis stricta* 50 - *Hierochloe pauciflora* 10	5	6.2	(active layer 30cm)	264	0E
Calamagrostis stricta - Carex aquatilis	-	-	-	Brant River	0E
CAREX AQUATILIS					
Carex aquatilis 20 - *Calamagrostis stricta* 20 - *Menyanthes trifoliata* 20	-15	5.8	>1.2	823	2E
Calliergon giganteum 20,70 - *Carex aquatilis* 3 5,50 (- *Paludella squarrosa - C. diandra*)	-5,-15	6.3,6.0	0.3,0.5	339 373	0E 1E
(Open water 100) - *Carex aquatilis* 90 - *C. chordorrhiza* 10 - *Scorpidium scorpoides* 10	-30	5.8	>2.0 (ice lens at 50 cm)	10B	0E
Carex aquatilis 65 - (open water 40) - *Chamaedaphne calyculata* 15 - *Scirpus hudsonianus* 10	0	6.0	2.3	289	1E
Carex aquatilis - Poa arctica - Salix planifolia - Petasites frigidus - Epilobium palustre (Maycock 1979)	-	-	-	-	0E
CAREX LENTICULARIS					
Carex lenticularis - Eleocharis acicularis (karst sinkhole)	-	7.4	-	Attawapiskat	2E
CAREX SAXATILIS					
Carex saxatilis 30,60 - *Salix* spp. 1,2 - *Triglochin maritima* 1,1	-10,-20	6.3,6.7	0.3,0.3	265 286	0E 1E
CAREX VIRIDULA					
Carex viridula - Juncus pelocarpus - Eleocharis compressa (drained fen pond)	-	-	-	402	2E
EQUISETUM ARVENSE					
Equisetum arvense (Maycock 1979)	-	-	-	-	0E
EQUISETUM VARIEGATUM					
Equisetum variegatum - Carex aquatilis - C. microglochin - C. limosa - Pedicularis groenlandica (Maycock 1979; Kershaw 1974, series C)	-	-	-	Pen Islands	0E
SCIRPUS CYPERINUS					
Scirpus cyperinus - Glyceria grandis - Carex vulpinoidea (drained beaver pond)	-	-	-	5°14'N, 83°18'W	1E
SHRUB-RICH MEADOW MARSH					
SALIX – MYRICA GALE – BETULA PUMILA					
Salix candida - Myrica gale - Betula pumila - Salix spp.	-	-	-	SW James Bay	2E
Salix candida 15 - *Carex limosa* 20 - *Equisetum fluviatile* 6 - *Myrica gale* 5 (- *Scorpidium scorpioides* 40 - *Campylium stellatum* 15)	-	-	-	SW James Bay	2E

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LOWSHRUB AND DWARF-SHRUB MEADOW MARSH					
Note: Includes exposed northern sites with >30cm peat, part of tundra wetland series; see also site types under OPEN DWARF-SHRUB FEN, above.					
BETULA PUMILA					
Betula pumila - Salix glauca (Maycock 1979)	-	-	-	-	0E
MYRICA GALE					
Myrica gale - Chamaedaphne calyculata - Betula pumila - Kalmia polifolia - Smilacina trifolia (Maycock 1979)	-	-	-	-	0E
SALIX BRACHYCARPA					
Festuca rubra 50 - *Calamagrostis stricta* 25 - *Salix brachycarpa* 15 - *S. candida* 10 - *S. glauca* 5	-	-	0.05	55°20'N,85°12'W	0E
Salix brachycarpa	-	-	-	Shagamu	0E
SALIX CANDIDA					
Scorpidium scorpioides 40 - *Salix candida* 15 - *Carex limosa* 20 - *Menyanthes trifoliata* 5 -*Campylium stellatum* 15	-	-	0.35	SW James Bay	2E
Salix candida - S. glauca	-	-	-	Partridge Island	0E
Salix candida - Carex aquatilis (Maycock 1979)	-	-	-	-	0E
SALIX GLAUCA					
Salix glauca - Carex aquatilis - Equisetum arvense - S. myrtillifolia - S. pellita (Maycock 1979; Kershaw 1974, series D)	-	-	-	Pen Islands	0E
Salix glauca 26 - *S. myrtillifolia* 25 - *Potentilla fruticosa* 15 - *Agropyron* spp. (riparian tundra meadow marsh)	-	-	-	Shagamu	0E
Salix glauca - S. candida - Juncus balticus - Carex paleacea	-	-	-	SW James Bay	2E
Salix glauca - S. candida - Taraxacum ceratophorum - Senecio aureus	-	-	-	SW James Bay	2E
SALIX PELLITA					
Salix pellita - S. cordata - Alnus rugosa	-	-	-	Attawapiskat	2E
SALIX PLANIFOLIA					
Salix planifolia - S. arctophila - S. candida - Betula glandulosa - Carex spp.	-	-	-	Shagamu	0E
Salix planifolia - Salix candida (Maycock 1979)	-	-	-	-	0E
Salix planifolia - S. candida - S. glauca (Maycock 1979)	-	-	-	-	0E
ESTUARINE					
SUPRATIDAL MEADOW MARSH					
ANEMONE CANADENSIS					
Anemone canadensis - Thalictrum venulosum- Smilacina stellata (Riley and McKay 1980)	-	-	-	Shipsands	2E
AGROSTIS GIGANTEA					
Agrostis gigantea (Riley and McKay 1980)	-	-	-	Shipsands	2E
CAREX RECTA					
Carex recta - Equisetum variegatum - Angelica atropurpurea (Riley and McKay 1980)	-	-	-	Arnold Point	2E
Carex recta - Menyanthes trifoliata - Angelica atropurpurea (Riley and McKay 1980)	-	-	-	Arnold Point	2E

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CAREX LIMOSA					
Carex limosa - Carex magellanica - Carex aquatilis - Rumex occidentalis (Riley and McKay 1980)	-	-	-	Arnold Point	2E
EQUISETUM VARIEGATUM					
Equisetum variegatum[100] (Riley and McKay 1980)	-	-	-	Arnold Point	2E
FESTUCA RUBRA					
Festuca rubra (with *Potentilla anserina* var. *groenlandica, Ranunculus crista-galli, Hordeum jubatum, Cicuta maculata, Hierochloe odorata*) (Riley and McKay 1980)	-	-	-	Shipsands	2E
JUNCUS BALTICUS					
Juncus balticus [70] *- Petasites sagittatus - Festuca rubra* (Riley and McKay 1980)	-	-	-	Shipsands	2E
RHINATHUS CRISTA-GALLI					
Rhinanthus crista-galli - Festuca rubra - Castilleja septentrionalis - Hierochloe odorata - Epilobium leptophyllum (Riley and McKay 1980)	-	-	-	Shipsands	2E
INTERTIDAL MARSH					
BIDENS HYPERBOREA					
Bidens hyperborea - Sagittaria latifolia - Alisma plantago-aquatica (Riley and McKay 1980)	-	-	-	Shipsands	2E
CAREX PALEACEA					
Carex paleacea [28] *- Potentilla anserina* var. *groenlandica* [14] *- Ranunculus cymbalaria* [11] *- Triglochin maritima* [8] (Riley and McKay 1980)	-	-	-	Shipsands	2E
Carex paleacea [34] *- Festuca rubra* [11] *- Potentilla anserina* var. *groenlandica* [11] *- Triglochin maritima* [5] (Riley and McKay 1980)	-	-	-	Shipsands	2E
CAREX RECTA					
Carex recta - Carex aquatilis (Riley and McKay 1980)	-	-	-	Shipsands	2E
EQUISETUM FLUVIATILE					
Equisetum fluviatile - Juncus nodosus - Carex recta - Eleocharis smallii (Riley and McKay 1980)	-	-	-	Shipsands	2E
HIPPURIS VULGARIS					
Hippuris vulgaris - Eleocharis smallii (Riley and McKay 1980)	-	-	-	Shipsands	2E
JUNCUS NODOSUS					
Juncus nodosus - Equisetum fluviatile - Carex utriculata (Riley and McKay 1980)	-	-	-	Shipsands	2E
LYSIMACHIA THYRSIFLORA					
Lysimachia thyrsiflora - Hippuris vulgaris - Sparganium spp. (Riley and McKay 1980)	-	-	-	Shipsands	2E
POTENTILLA ANSERINA var. GROENLANDICA					
Potentilla anserina var. *groenlandica* (with *Carex paleacea, Aster robbynsianus, Hierochloe odorata*) (Riley and McKay 1980)	-	-	-	Shipsands	2E
PUCCINELLIA PHRYGANODES					
Puccinellia phryganodes (Riley and McKay 1980)	-	-	-	Shipsands	2E
Puccinellia phryganodes - Triglochin palustris - Salicornia europaea (Riley and McKay 1980)	-	-	-	Shipsands	2E
SAGITTARIA LATIFOLIA					
Sagittaria latifolia - Eleocharis smallii - Scirpus validus (Riley and McKay 1980)	-	-	-	Shipsands	2E

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SCIRPUS AMERICANUS					
Scirpus americanus - Scirpus validus - Eleocharis smallii - Triglochin palustris (Riley and McKay 1980)	-	-	-	Shipsands	2E
SCIRPUS VALIDUS					
Scirpus validus (Riley and McKay 1980)	-	-	-	Shipsands	2E
Scirpus validus - Eleocharis smallii - Ranunculus cymbalaria - Sium suave - Carex paleacea (Riley and McKay 1980)	-	-		Shipsands	2E
Scirpus validus - Hippuris vulgaris - Alisma triviale (Riley and McKay 1980)	-	-	-	Shipsands	2E
SENECIO CONGESTUS					
Senecio congestus (with *Eleocharis smallii, Puccinellia phryganodes, Catabrosa aquatica, Carex paleacea, Salicornia europaea*) (Riley and McKay 1980)	-	-	-	Shipsands	2E
COASTAL					
SUPRATIDAL MEADOW MARSH					
CALAMAGROSTIS STRICTA					
Calamagrostis stricta (with *Deschampsia cespitosa, Festuca rubra, Hordeum jubatum, Juncus balticus*) (Riley and McKay 1980)	-	-	-	SW James Bay	2E
Calamagrostis stricta (- *Salix candida*) (Maycock 1979)	-	-	-	-	0E
CAREX GLAREOSA					
Carex glareosa - C. mackenziei - Potentilla anserina var. *groenlandica - Calamagrostis stricta - Ranunculus cymbalaria*	-	-	-	Shagamu	0E
Carex glareosa - Festuca rubra - Hordeum jubatum - Potentilla anserina var. *groenlandica*	-	-	-	Shagamu, Little Cape	0E
Carex glareosa – Menyanthes trifoliata	-	-	-	SW James Bay	2E
CAREX PALEACEA					
Carex paleacea 30-80 (with *Utricularia vulgaris, Eleocharis smallii, Hippuris vulgaris, Ranunculus aquatilis, Cicuta mackenzieana, Epilobium* spp.) (Riley and McKay 1980)	-	-	-	SW James Bay	2E
Carex paleacea 35 - *Juncus balticus* 6 - *Eleocharis smallii* 5 - *Cicuta mackenzieana* 5 – *Amblystegium riparium* 5	-	-	-	SW James Bay	2E
DESCHAMPSIA CESPITOSA					
Deschampsia cespitosa (Riley and McKay 1980, Ringius 1980)	-	-	-	SW James Bay	2E
Deschampsia cespitosa - Carex subspathacea (Maycock 1979)	-	-	-	-	0E
ELEOCHARIS SMALLII					
Eleocharis smallii (Riley and McKay 1980)	-	-	-	SW James Bay	2E
FESTUCA RUBRA					
Festuca rubra 50-100 - *Potentilla anserina* var. *groenlandica* (Riley and McKay 1980)	-	-	-	SW James Bay	2E
Festuca rubra - Hordeum jubatum (Riley and McKay 1980)	-	-	-	SW James Bay	2E
Festuca rubra - Deschampsia cespitosa (Riley and McKay 1980)	-	-	-	SW James Bay	2E
Festuca rubra - Scirpus rufus (Riley and McKay 1980)	-	-	-	SW James Bay	2E
Festuca rubra 90 - *Carex paleacea* 20 - *Triglochin maritima* 15	-	-	-	SW James Bay	2E
Festuca rubra 90 - *Triglochin maritima* 15 - *Deschampsia cespitosus* 5 - *Potentilla anserina* var. *groenlandica* 17	-	-	-	SW James Bay	2E

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Festuca rubra - Calamagrostis stricta - Dupontia fisheri (with *Lomatogonium rotatum, Rhinanthus crista-galli - Parnassia palustris, Juncus balticus*)	-	-	-	Shagamu	0E
Festuca rubra [43] - *Potentilla anserina var. groenlandica* [17]- *Carex subspathacea* [6] - *Chrysanthemum arcticum* [5] - *Plantago maritima* [4]	-	-	-	Shagamu	0E
Festuca rubra – Carex glareosa- C. subspathacea	-	-	-	Fog Point	0E
HIPPURIS VULGARIS					
Hippuris vulgaris (Riley and McKay 1980)	-	-	-	SW James Bay	2E
Hippuris vulgaris - Carex glareosa - C. aquatilis	-	-	-	Shagamu	0E
Hippuris vulgaris - Potamogeton filiformis - Ranunculus aquatilis	-	8.9 (conductivity 2260 μmhos)	-	Shagamu, Little Cape	0E
JUNCUS BALTICUS					
Juncus balticus	-	-	-	Shagamu	0E
Juncus balticus - Calamagrostis stricta (with *Lathyrus palustris, Parnassia palustris*) (Riley and McKay 1980)	-	-	-	SW James Bay	2E
MENYANTHES TRIFOLIATA					
Menyanthes trifoliata [80] - *Carex paleacea* [3]	-3	-	-	SW James Bay	2E
MYRIOPHYLLUM SIBIRICUM					
Myriophyllum sibiricum (Riley and McKay 1980)	-	-	-	SW James Bay	2E
Myriophyllum sibiricum - Potamogeton filiformis - Ranunculus cymbalaria	8.9	(conductivity 2260 μmhos)	-	Shagamu	0E
PETASITES SAGITTATUS					
Petasites sagittatus - Carex glareosa - C. aquatilis	-	-	-	Shagamu	0E
POTAMOGETON FILIFORMIS					
Potamogeton filiformis (Riley and McKay 1980)	-	-	-	SW James Bay	2E
SCIRPUS AMERICANUS					
Scirpus americanus - Sparganium chlorocarpum (Riley and McKay 1980)	-	-	-	SW James Bay	2E
Scirpus americanus [45] - *Hordeum jubatum* [3] - *Ranunculus cymbalaria* [2]	-	-	-	SW James Bay	2E
SCIRPUS RUFUS					
Scirpus rufus	-	-	-	Ekwan Point Shipsands	1E 2E
SENECIO CONGESTUS					
Senecio congestus	-	-	-	Ekwan Shipsands, North Pt.	1E 2E
ZANNICHELLIA PALUSTRIS					
Zannichellia palustris - Potamogeton filiformis - Callitriche hermaphroditica	-	-	-	Shagamu	0E-
Zannichellia palustris (Riley and McKay 1980)	-	-	-	SW James Bay	2E
INTERTIDAL MARSH					
CAREX GLAREOSA					
Carex glareosa - Puccinellia phryganodes - Hippuris vulgaris	-	-	-	Shagamu	0E

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CAREX MACKENZIEI					
Carex mackenziei - C. glareosa (with *Hippuris vulgaris*)	-	9.4 (conductivity 2570 μmhos)	-	Shagamu	0E
Carex mackenziei (Ringius 1980)	-	-	-	Kapiskau	2E
CAREX PALEACEA					
Carex paleacea (Riley and McKay 1980)	-	-	-	Ekwan Point SW James Bay	1E 2E
CAREX SUBSPATHACEA					
Carex subspathacea [64] - *Potentilla anserina* var. *groenlandica* [20] - *Puccinellia phryganodes* [15] (with *Festuca rubra, Dupontia fisheri*)	-	-	-	Shagamu	0E
ELEOCHARIS SMALLII					
Eleocharis smallii [10-80] (Riley and McKay 1980)	-	-	-	Ekwan Point SW James Bay	1E 2E
Eleocharis smallii - Carex paleacea - Hippuris vulgaris - Senecio congestus (Riley and McKay 1980)	-	-	-	SW James Bay	2E
Eleocharis smallii - E. pauciflora - Juncus alpinus (Maycock 1979)	-	-	-	-	0E
HIPPURIS TETRAPHYLLA					
Hippuris tetraphylla [34] - *Puccinellia phryganodes* [8] (with *Potentilla anserina* var. *groenlandica, Ranunculus cymbalaria*)	-	-	-	Shagamu	0E
Hippuris tetraphylla - Carex glareosa - Senecio congestus - C. subspathacea	-	-	-	Shagamu	0E
Hippuris tetraphylla (Riley and McKay 1980, Ringius 1980)	-	-	-	SW James Bay	2E
POTAMOGETON FILIFORMIS - POTAMOGETON PECTINATUS					
Potamogeton filiformis and/or *P. pectinatus* (with *Zannichellia palustris, Ruppia maritima, Eleocharis smallii, Scirpus maritimus, Hippuris vulgaris*) (Riley and McKay 1980)	-	-	-	SW James Bay	2E
POTENTILLA ANSERINA var GROENLANDICA					
Potentilla anserina var. *groenlandica* [40] - *Puccinellia phryganodes* [20] (with *Stellaria humifusa, Festuca rubra*)	-	-	-	Shagamu	0E
PUCCINELLIA PHRYGANODES					
Puccinellia phryganodes [5-90] (with *Plantago maritima, Carex paleacea, Potamogeton filiformis, P. pectinatus, Potentilla anserina* var. *groenlandica, Scirpus maritimus, Senecio congestus*) (Riley and McKay 1980)	-	-	-	SW James Bay	2E
Puccinellia phryganodes - Stellaria humifusa	-	-	-	Shagamu Ekwan Point	0E 1E
Puccinellia phryganodes - Carex glareosa	-	-	-	Shagamu, Fog Point	0E
Puccinellia phryganodes - Hippuris vulgaris	-	-	-	Shagamu	0E
Puccinellia phryganodes [36] - *Ranunculus cymbalaria* [10] - *Potentilla anserina* var. *groenlandica* [5] (*Stellaria humifusa*)	-	-	-	Shagamu	0E
SCIRPUS MARITIMUS					
Scirpus maritimus var. *paludosus* [10-80] (Riley and McKay 1980)	-	-	-	SW James Bay	2E
Scirpus maritimus var. *paludosus - Carex paleacea - Hippuris vulgaris - Senecio congestus*	-	-	-	SW James Bay	2E

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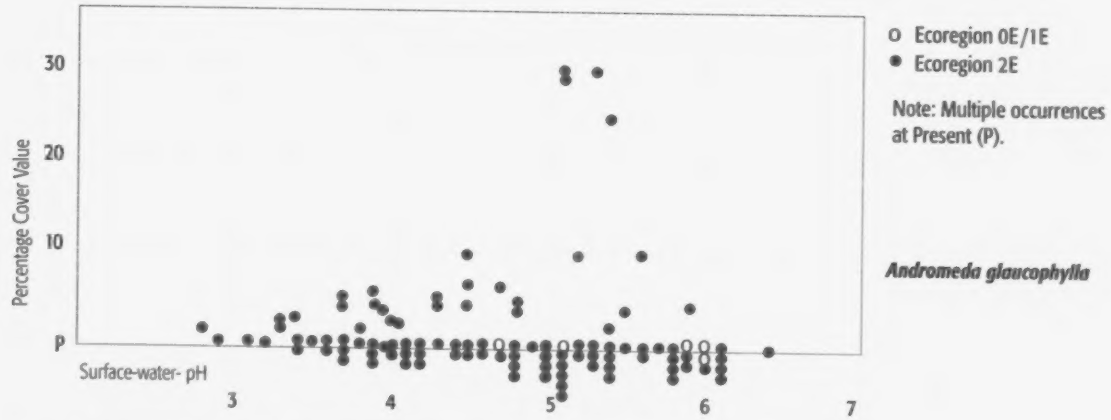
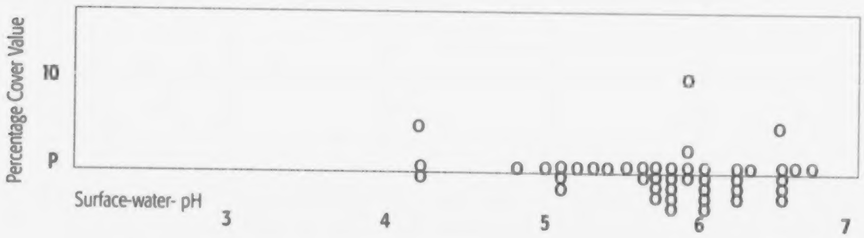
SENECIO CONGESTUS					
Senecio congestus (Riley and McKay 1980)	-	-	-	SW James Bay	2E
Senecio congestus - Hippuris vulgaris	-	-	-	Shagamu	0E
ZANNICHELLIA PALUSTRIS					
Zannichellia palustris (Riley and McKay 1980)	-	-	-	SW James Bay Ekwan Point	2E 1E
WATER					
SHALLOW WATER					
MENYANTHES TRIFOLIATA					
Menyanthes trifoliata – Carex paleacea	-	-	-	SW James Bay	2E
MYRIOPHYLLUM SIBIRICUM					
Myriophyllum sibiricum $^{80+}$	-	-	-	Shagamu	0E
Myriophyllum sibiricum - Carex aquatilis (with *Potamogeton pectinatus, P. filiformis, P. pusillus*)	-	8.4 (conductivity 790 μmhos)	-	Shagamu	0E
Myriophyllum sibiricum - Callitriche hermaphroditica - Zannichellia palustris - Ranunculus aquatilis - Potamogeton filiformis	-	9.4 (conductivity 580 μmhos)	-	Shagamu	0E
POTAMOGETON ALPINUS					
Leptodictyum riparium - Potamogeton alpinus - P. pusillus	up to -100	-	-	Aquatuk	1E
POTAMOGETON FILIFORMIS					
Potamogeton filiformis - Ranunculus aquatilis - Myriophyllum sibiricum (Maycock 1979)	-	-	-	-	0E
Potemogeton filiformis - Chara spp.	-	-	-	Kinoje	2E
POTAMOGETON GRAMINEUS					
Potamogeton gramineus - Potamogeton richardsonii	-	-	-	Kwataboahegan	2E
POTAMOGETON RICHARDSONII					
Potamogeton richardsonii - P. pectinatus - P. pusillus - Sagittaria cuneata (Maycock 1979)	-	-	-	-	0E
RANUNCULUS AQUATILIS (s.l.)					
Ranunculus aquatilis - Potamogeton pusillis - P. pectinatus - Myriophyllum sibiricum	-	7.7 (conductivity 580 μmhos)	-	Shagamu	0E
Ranunculus aquatilis - Potamogeton pectinatus - P. richardsonii - Myriophyllum sibiricum - Callitriche hermaphroditica	up to -100	-	-	Aquatuk	1E
Ranunculus aquatilis s.l. *- Hippuris vulgaris* (Maycock 1979)	-	-	-	-	0E
RANUNCULUS GMELINII					
Ranunculus gmelinii - Ranunculus hyperboreus	-	-	-	Shagamu	0E
DEEP WATER					
POTAMOGETON					
Potamogeton pectinatus - P. praelongus	>-100	-	-	Aquatuk	1E
Potamogeton natans	-	-	-	Kinoje	2E
Potamogeton richardsonii - P. pectinatus	-	-	-	Aquatuk Kinoje	1E 2E
NUPHAR					
Nuphar variegatum - Potamogeton natans	>-100	6.2	-	Aquatuk	1E
Nuphar variegatum - Potamogeton natans	-	-	-	Kinoje	2E
ZOSTERA					
Zostera marina	-	-	-	Offshore	1E, 2E

Appendix D
Cover Values and Surface-water pHs of Common Peatland Species

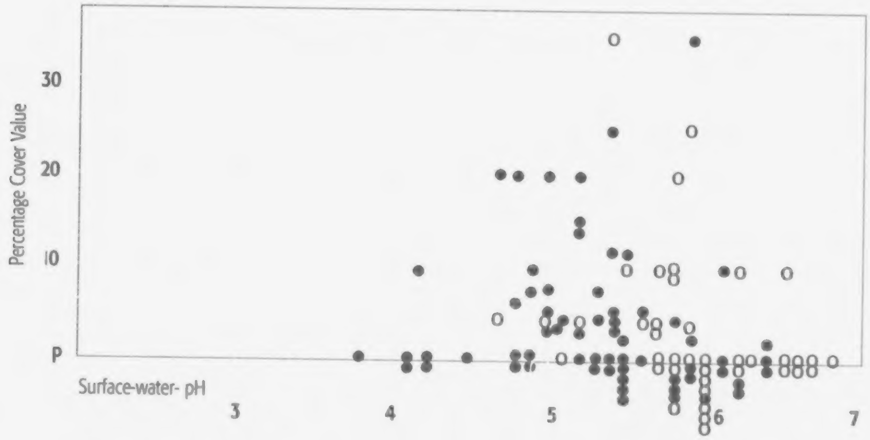
Alphabetical order by species binomial.



Andromeda glaucophylla



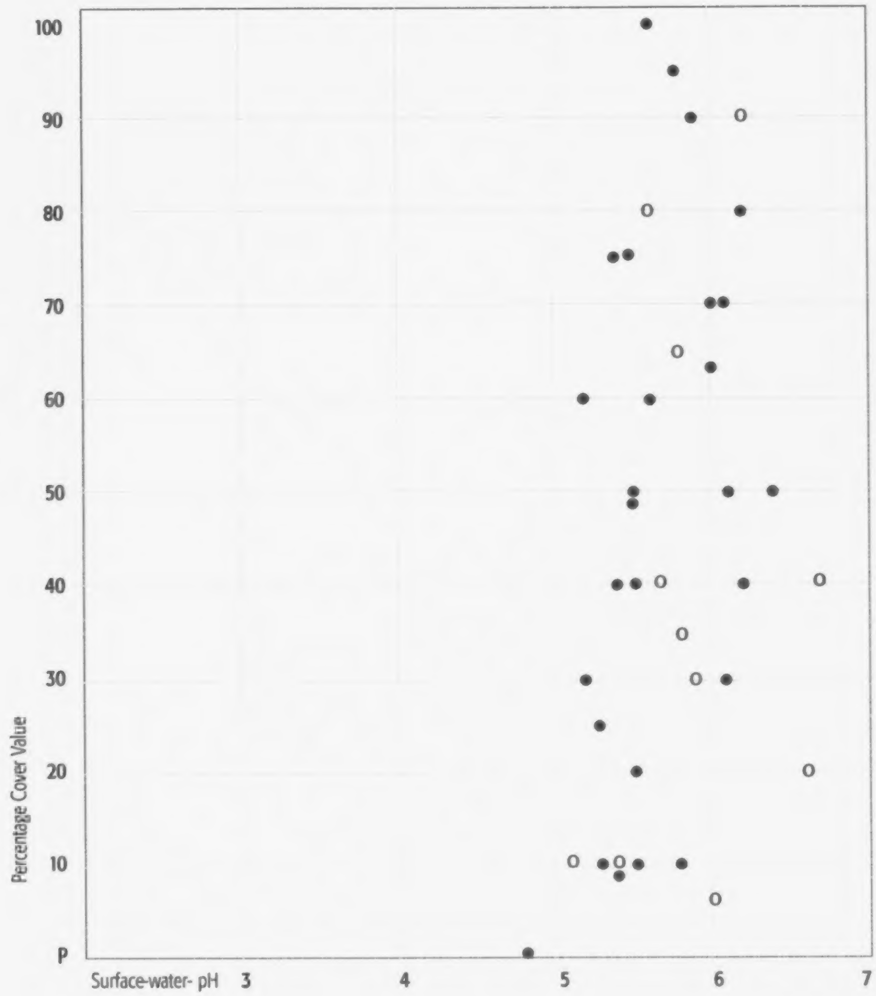
Andromeda polifolia



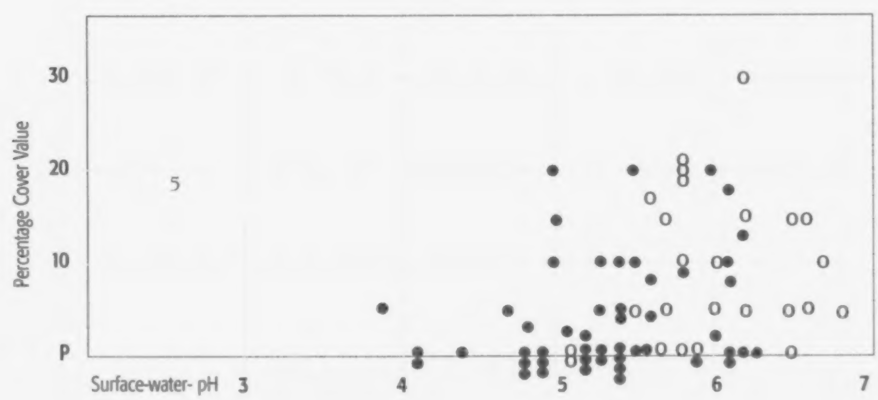
Betula glandulifera

o Ecoregion 0E/1E
• Ecoregion 2E

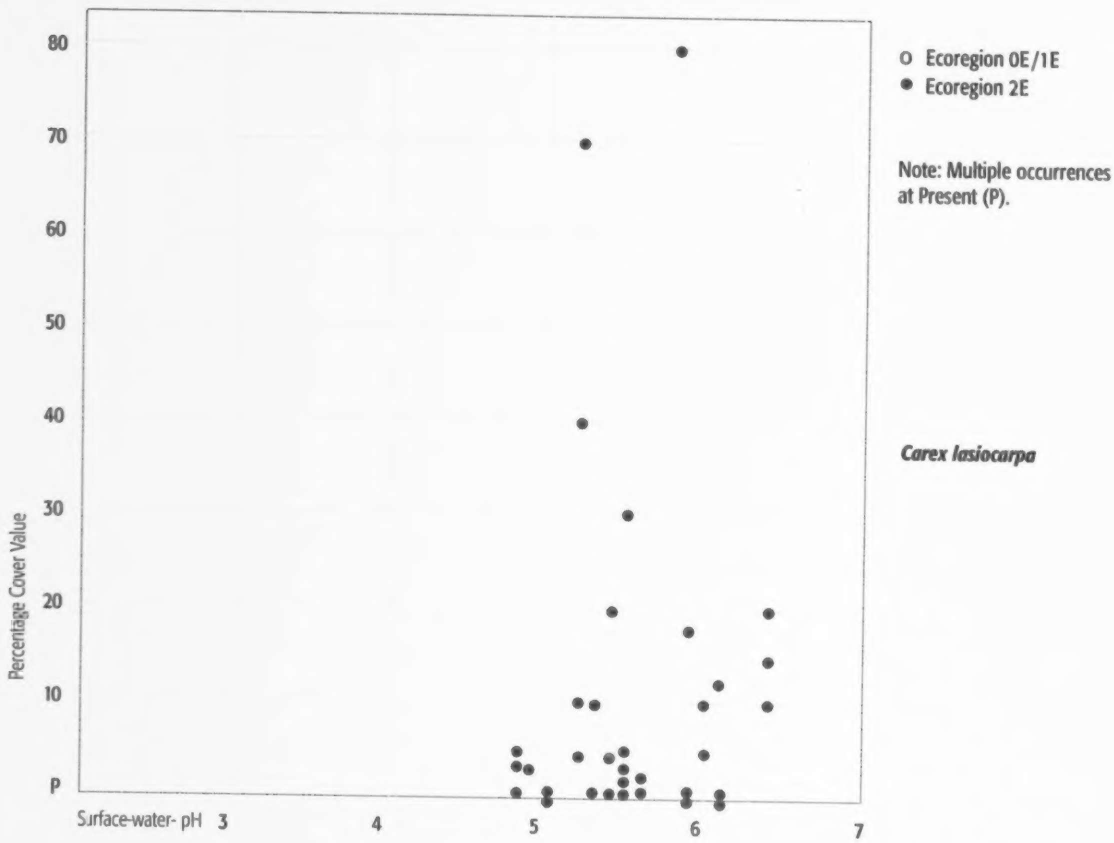
Campylium stellatum



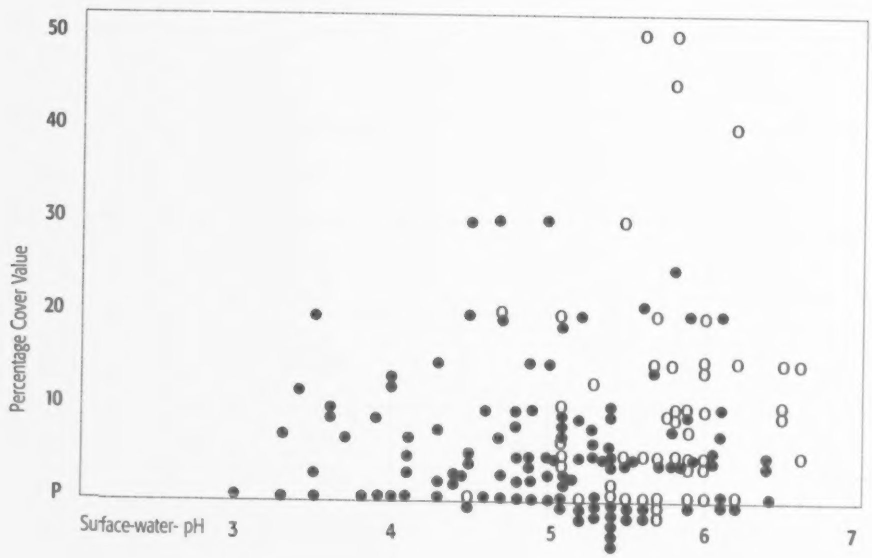
Carex chordororhiza



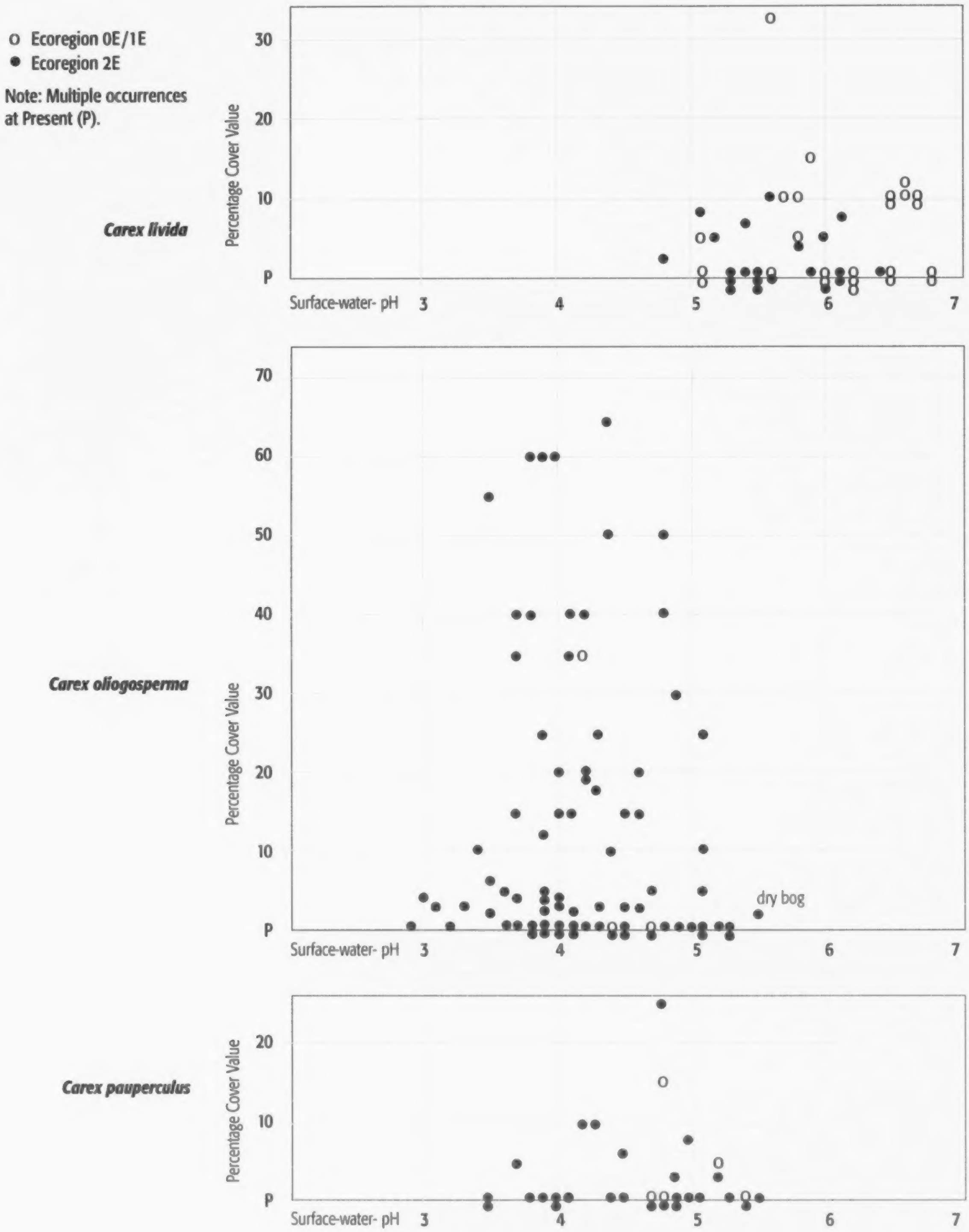
Note: Multiple occurrences at Present (P).

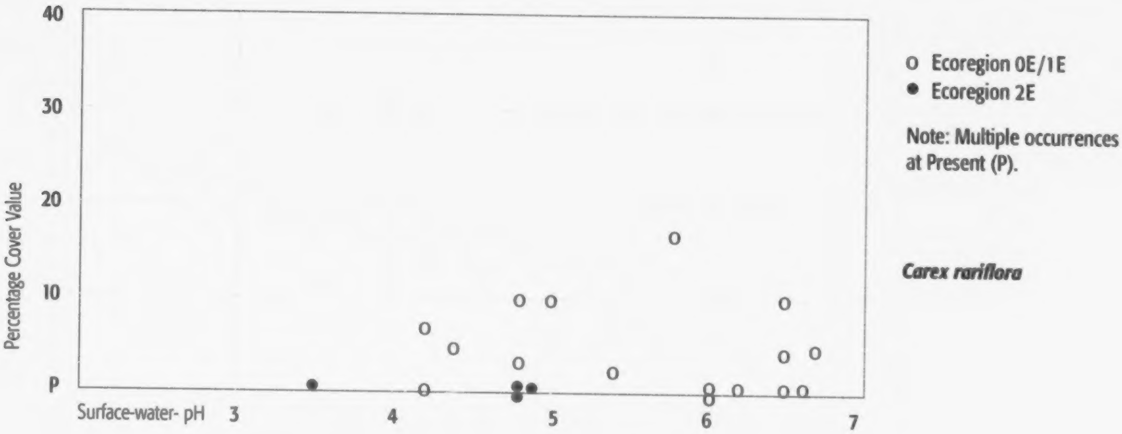


Carex lasiocarpa

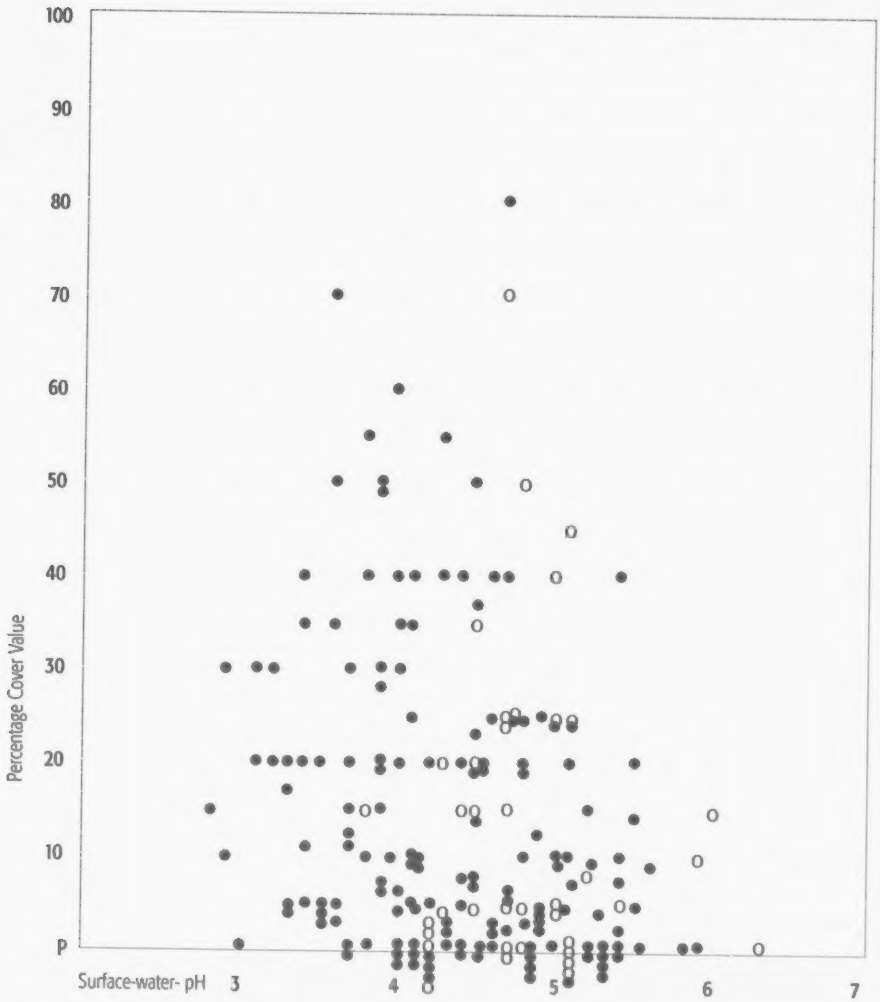


Carex limosa

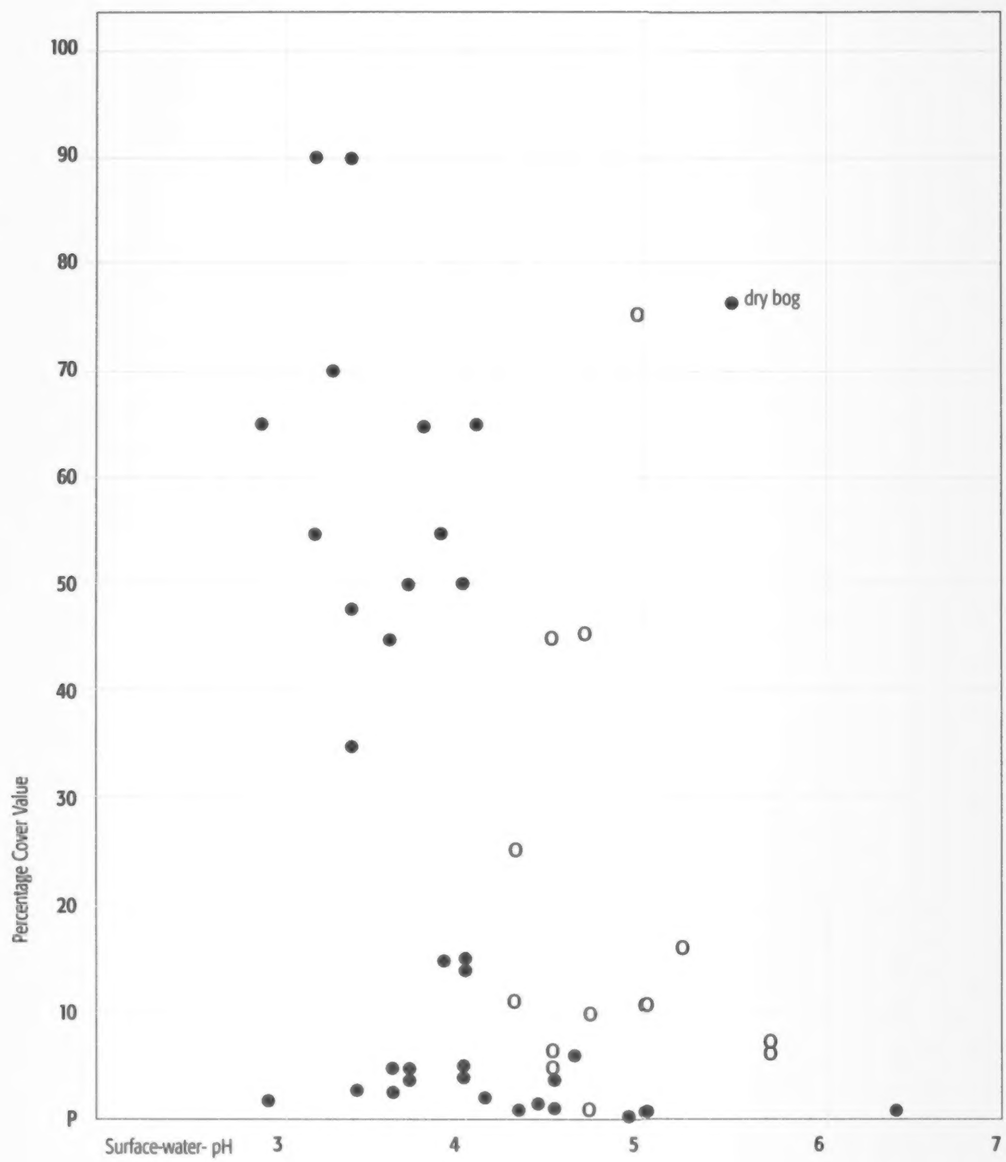

o Ecoregion 0E/1E
• Ecoregion 2E
Note: Multiple occurrences at Present (P).
Carex livida
Carex oliogosperma
Carex pauperculus
Percentage Cover Value
Surface-water- pH
dry bog
P
10
20
30
40
50
60
70
3
4
5
6
7



Carex rariflora

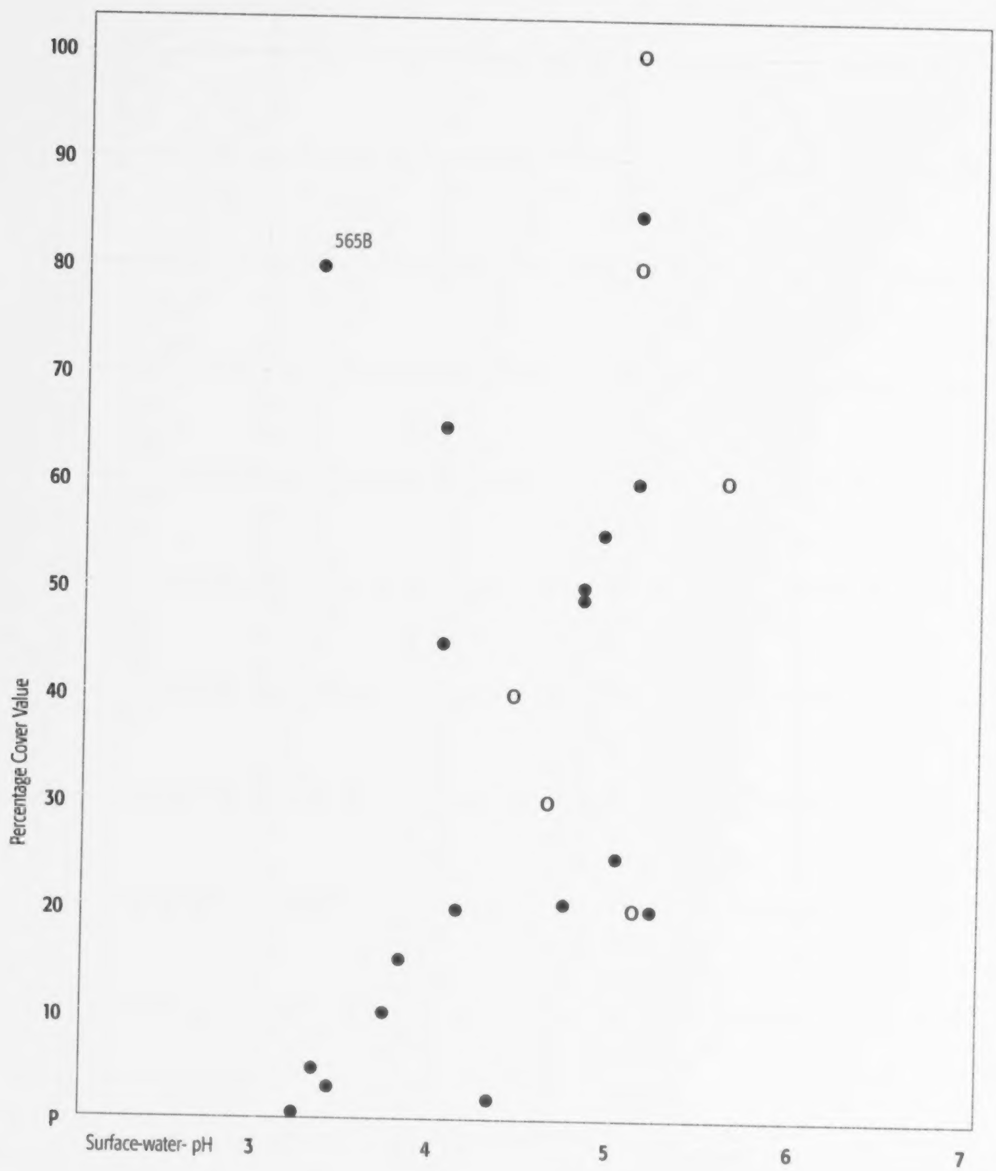


Chamaedaphne calyculata



Cladina rangiferina / mitis / alpestris

o Ecoregion 0E/1E
● Ecoregion 2E



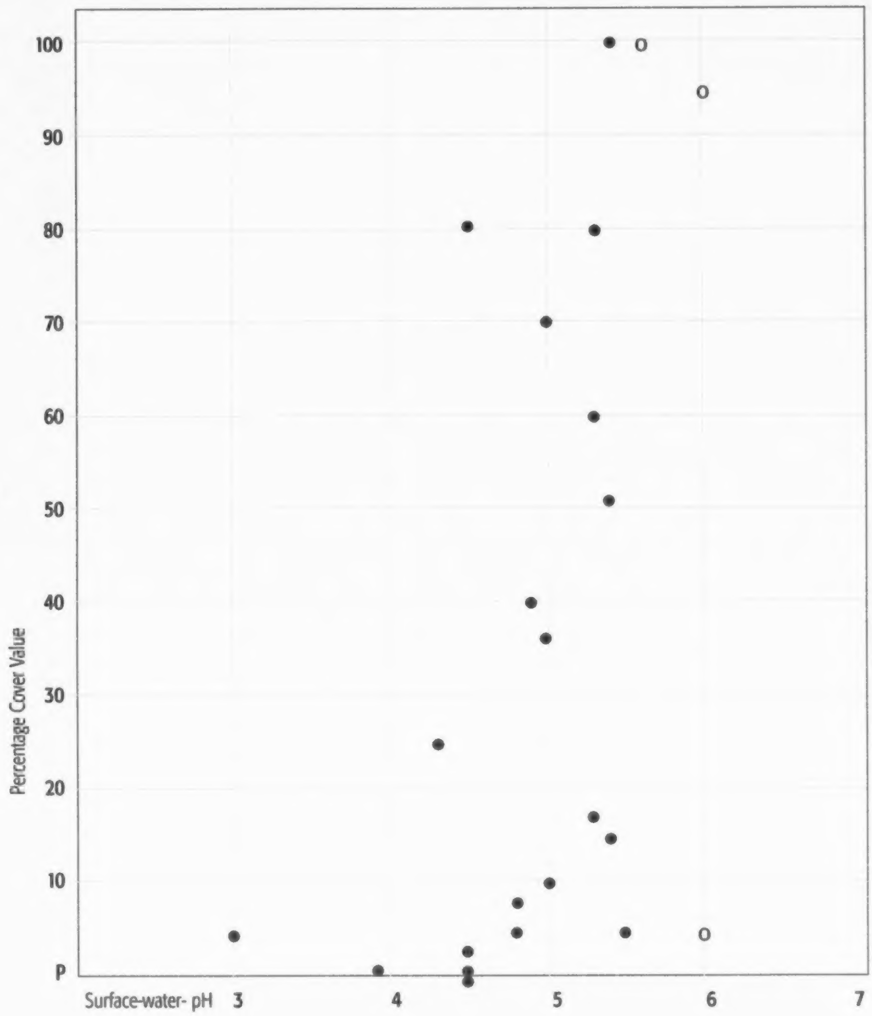
Cladopodiella fluitans

o Ecoregion 0E/1E
● Ecoregion 2E

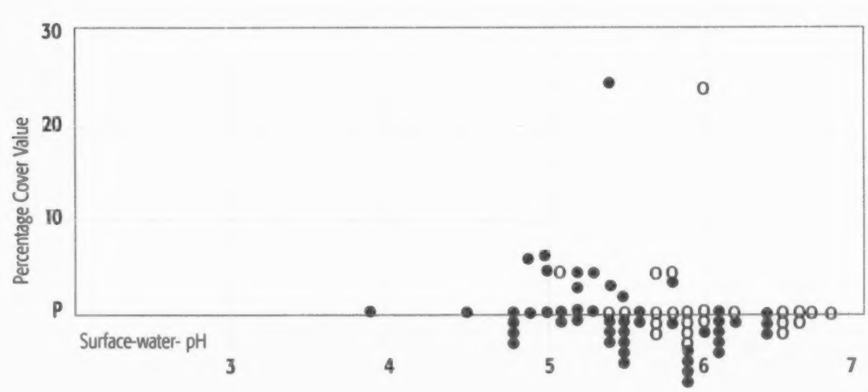
o Ecoregion 0E/1E
● Ecoregion 2E

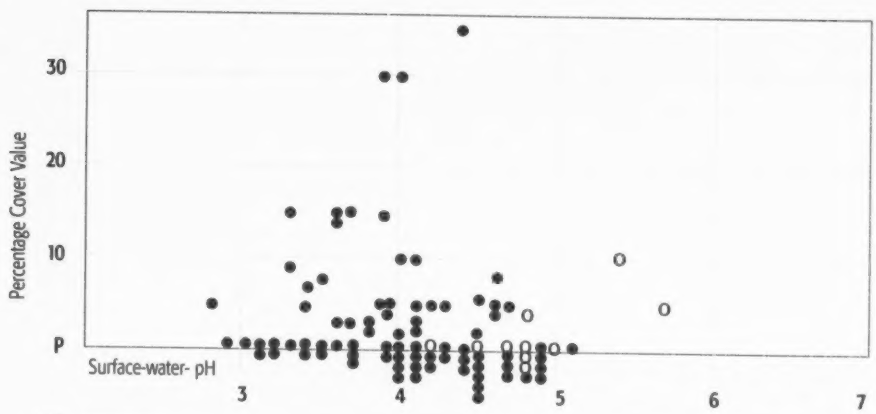
Note: Multiple occurrences at Present (P).

Drepanocladus exannulatus



Equisetum fluviatile

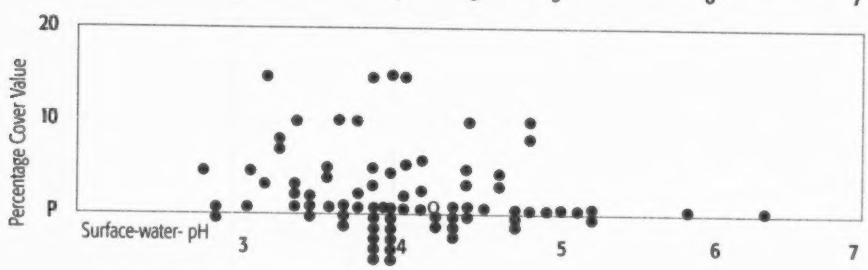




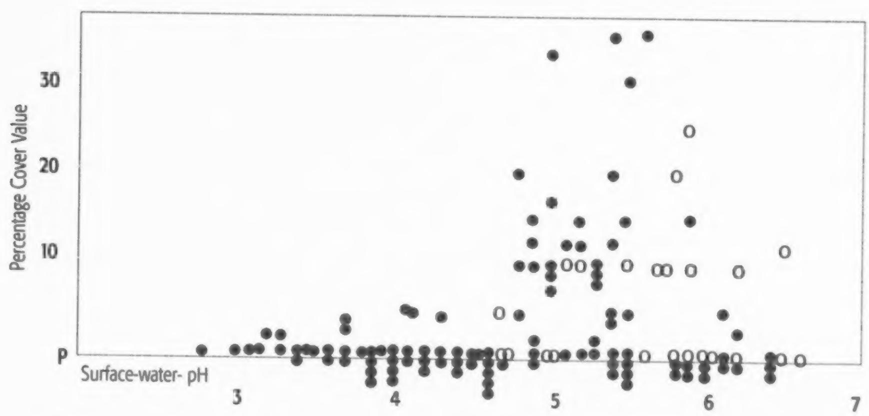
o Ecoregion 0E/1E
• Ecoregion 2E

Note: Multiple occurrences at Present (P).

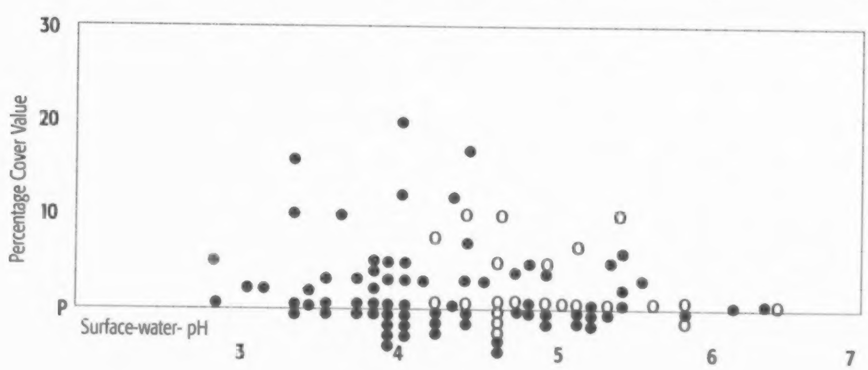
Eriophorum spissum



Kalmia angustifolia



Larix laricina



Ledum groenlandicum

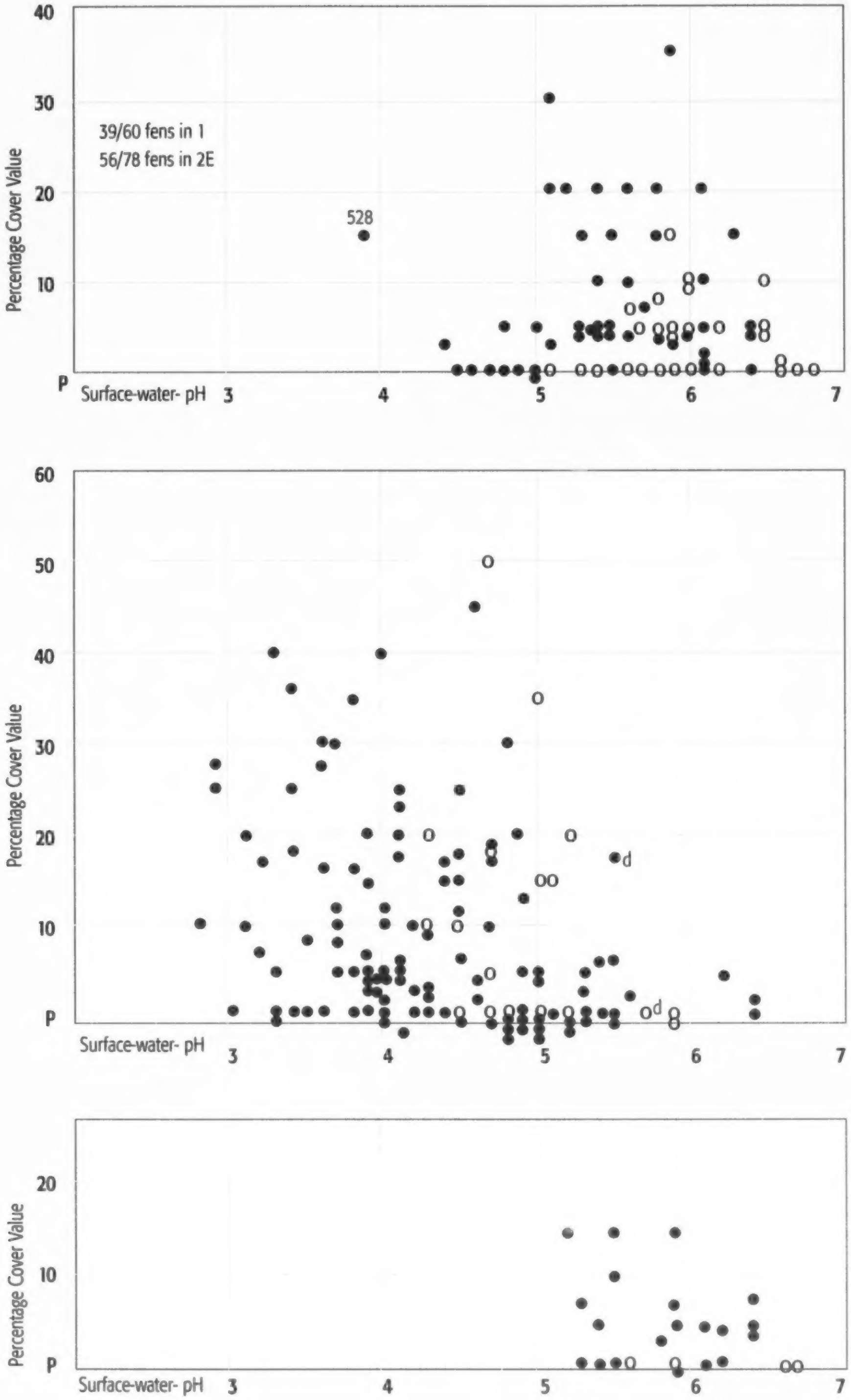
o Ecoregion 0E/1E
• Ecoregion 2E

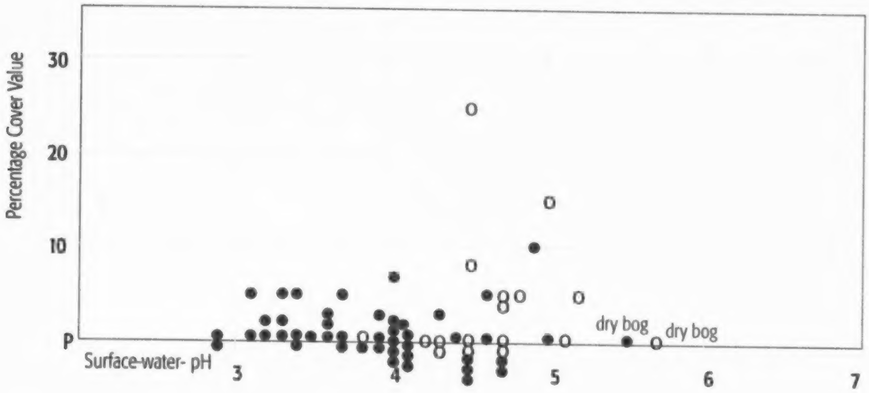
Note: Multiple occurrences at Present (P).

Menyantnes trifliata

Picea mariana

Potentilla fruticosa

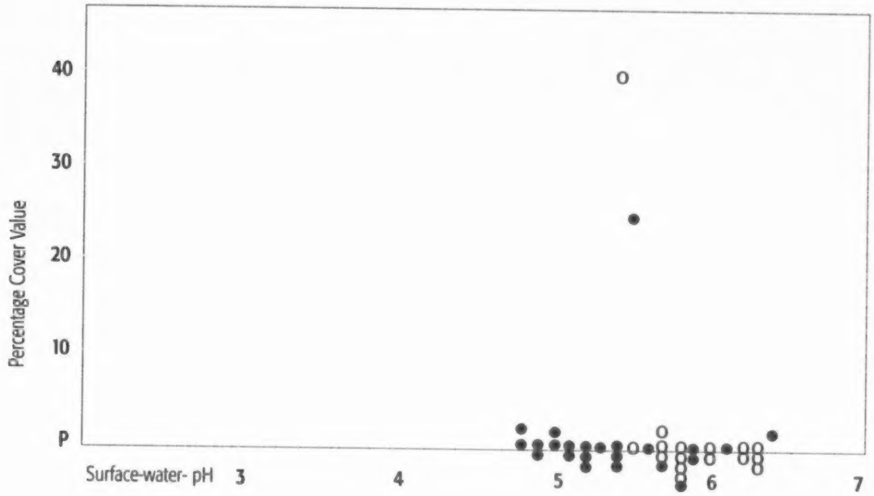




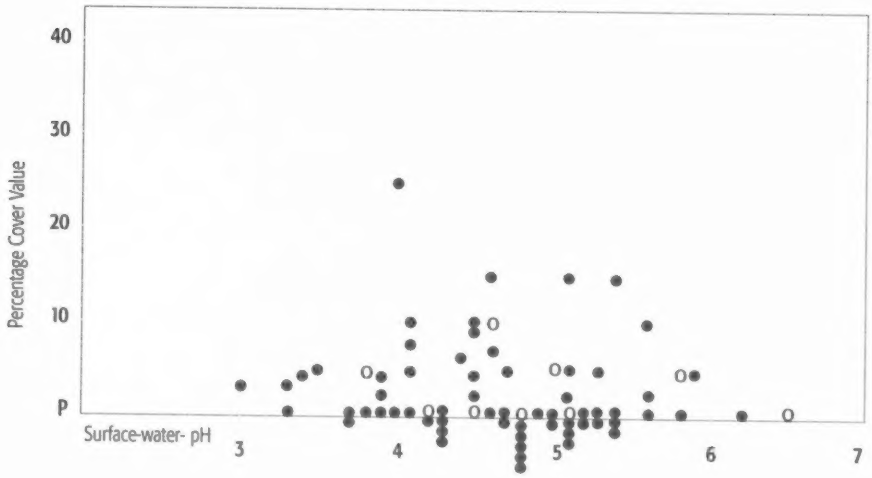
o Ecoregion 0E/1E
• Ecoregion 2E

Note: Multiple occurrences at Present (P).

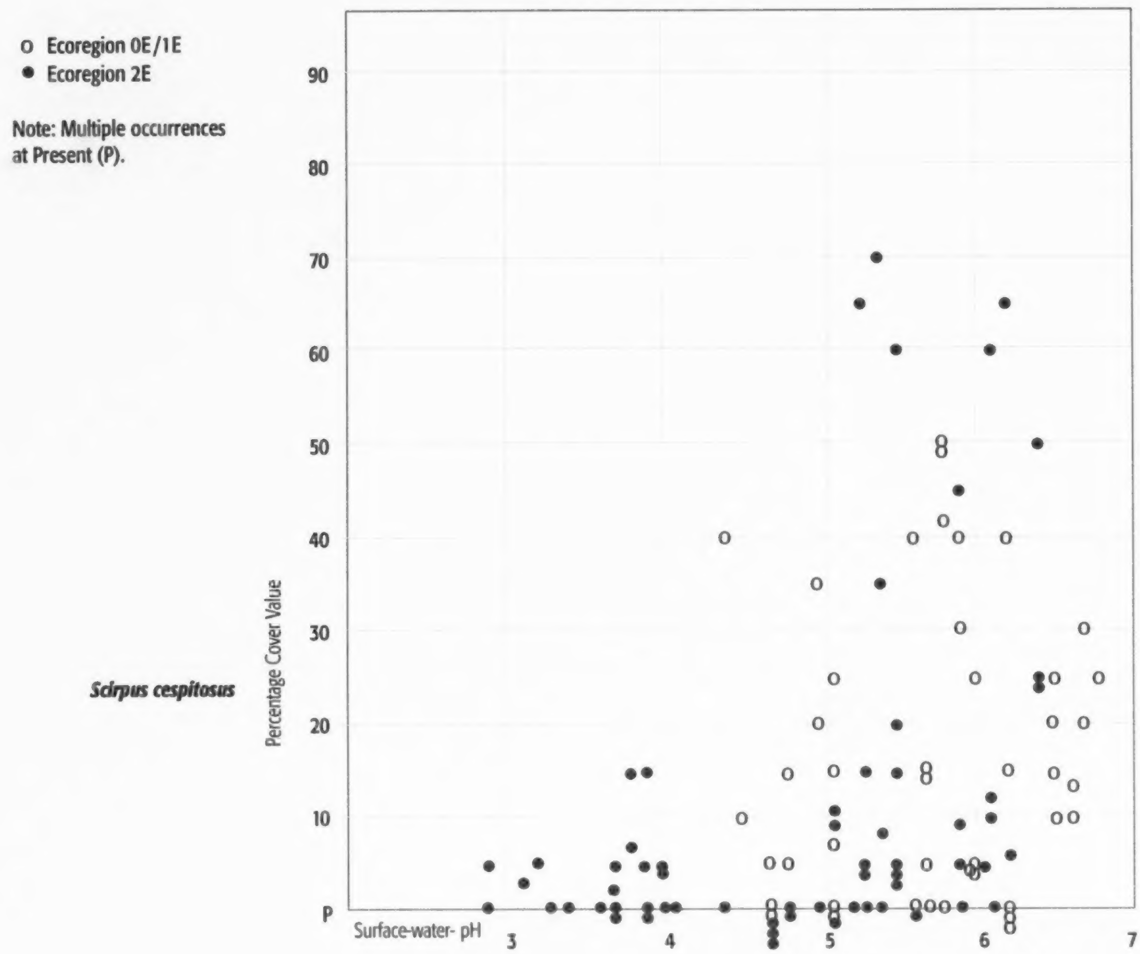
Rubus chamaemorus

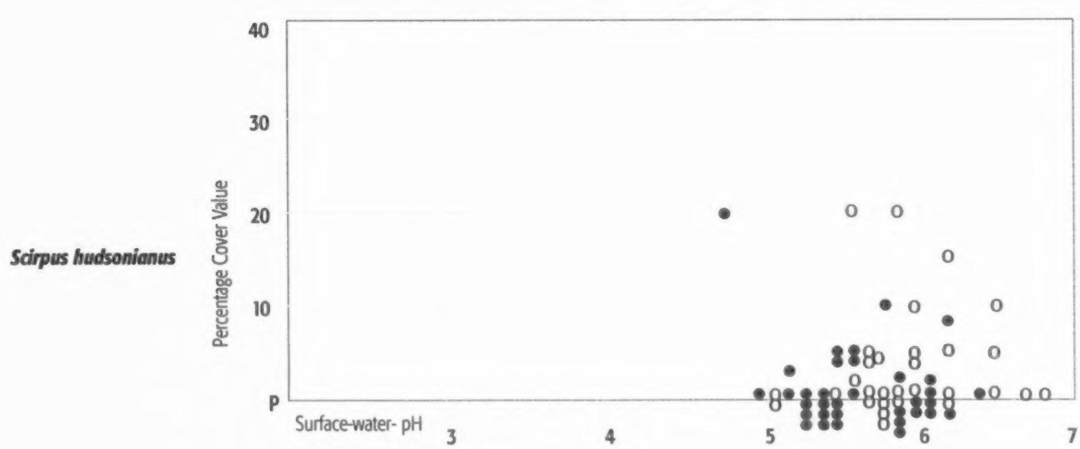


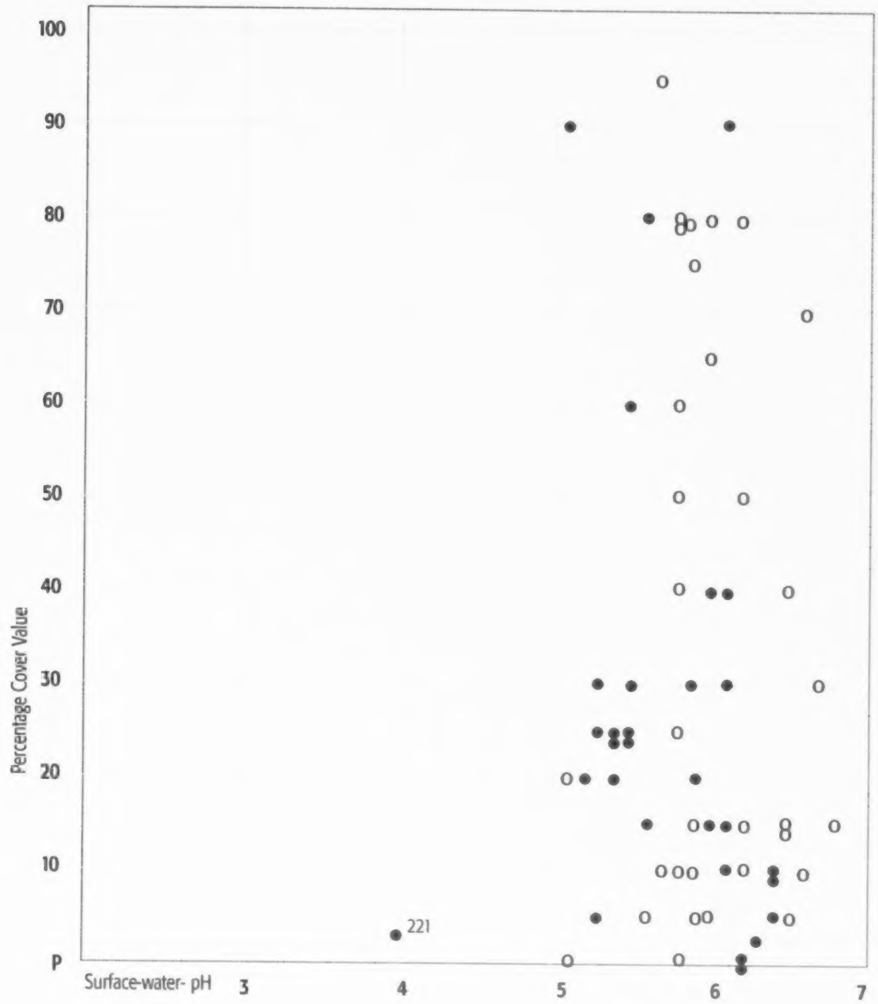
Salix pedicellaris



Scheuchzeria palustris


o Ecoregion 0E/1E
• Ecoregion 2E
Note: Multiple occurrences at Present (P).
Scirpus cespitosus
Percentage Cover Value
90
80
70
60
50
40
30
20
10
P
Surface-water- pH
3
4
5
6
7

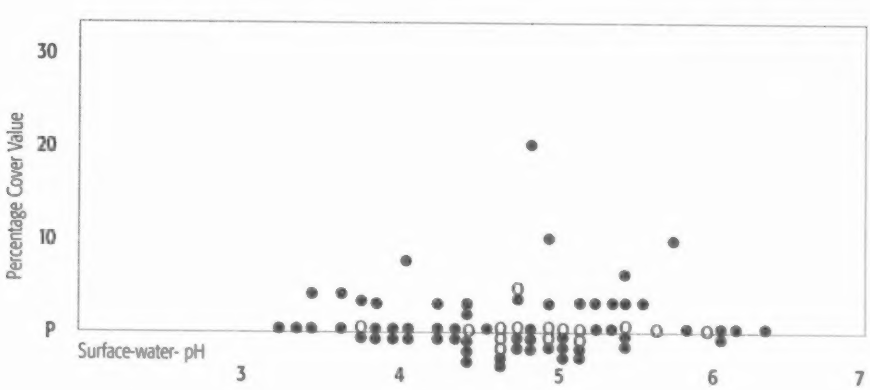

Scirpus hudsonianus
Percentage Cover Value
40
30
20
10
P
Surface-water- pH
3
4
5
6
7



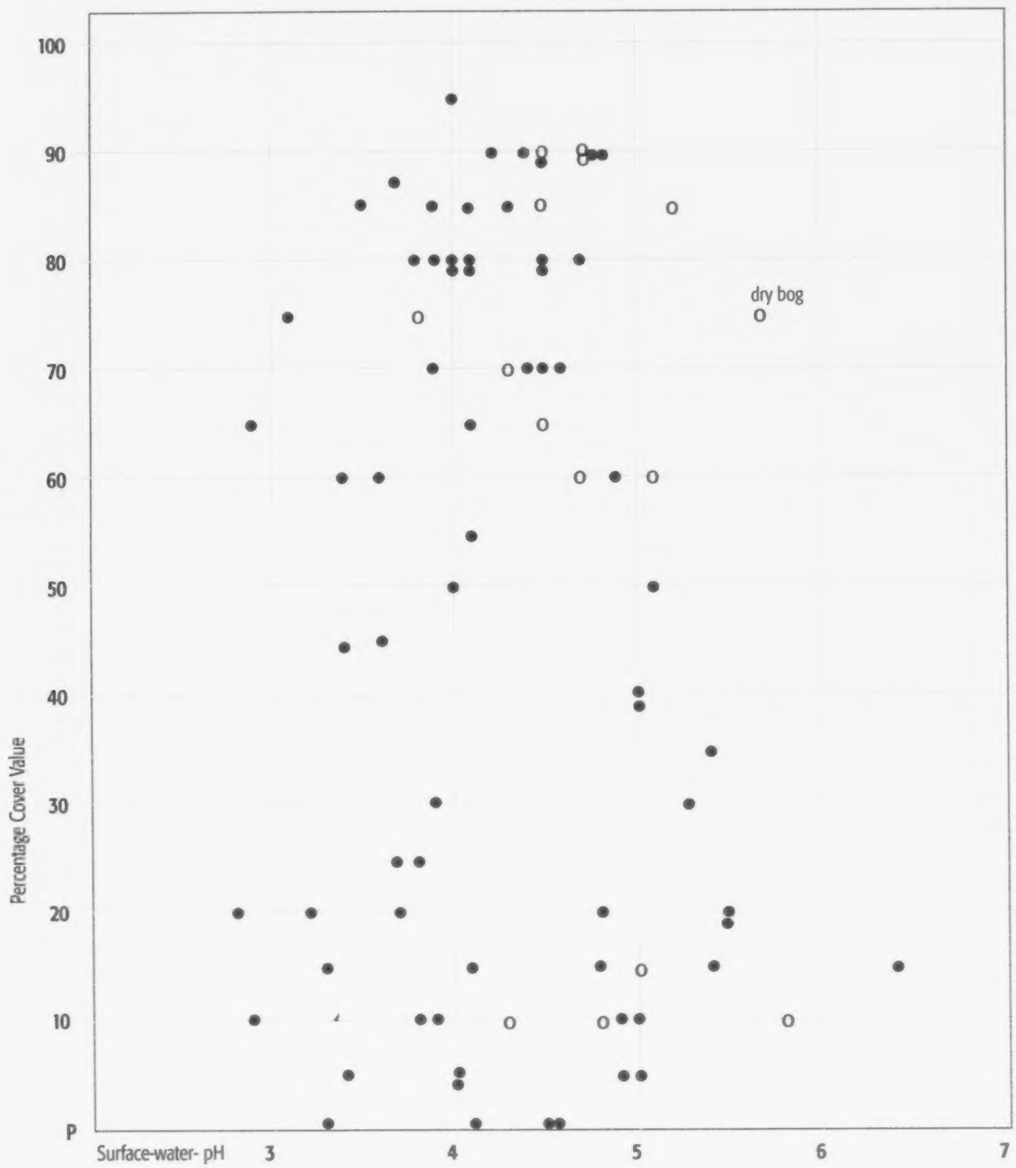
o Ecoregion 0E/1E
• Ecoregion 2E

Note: Multiple occurrences at Present (P).

Scorpidium scorpioides

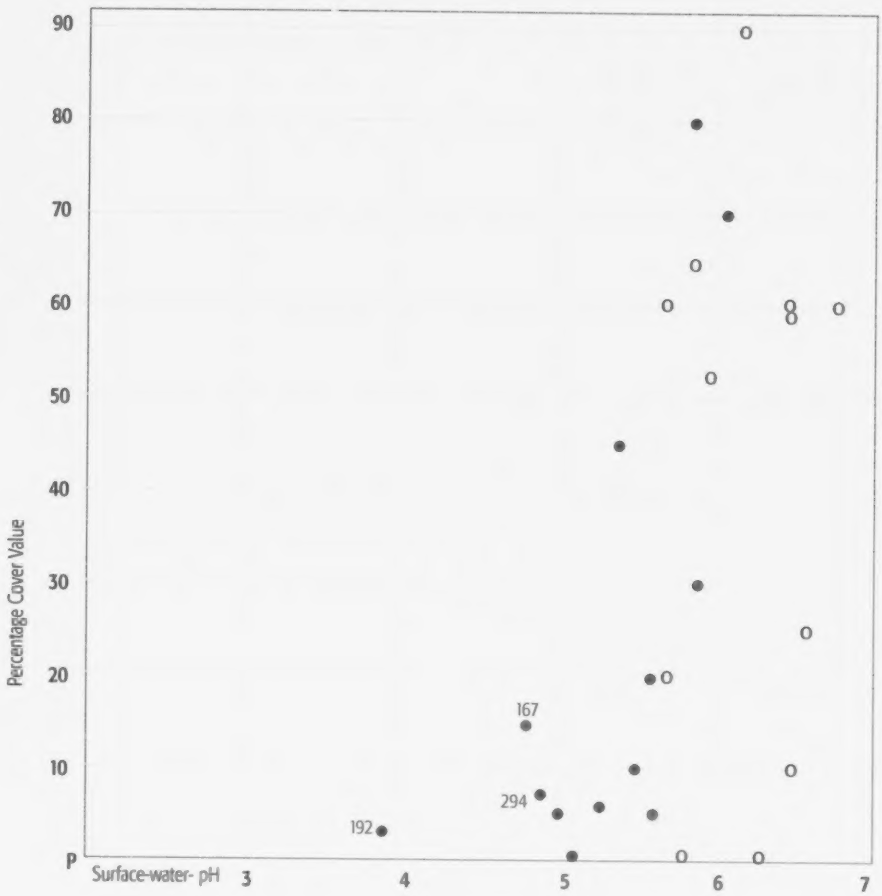


Smilacina trifolia



Sphagnum fuscum

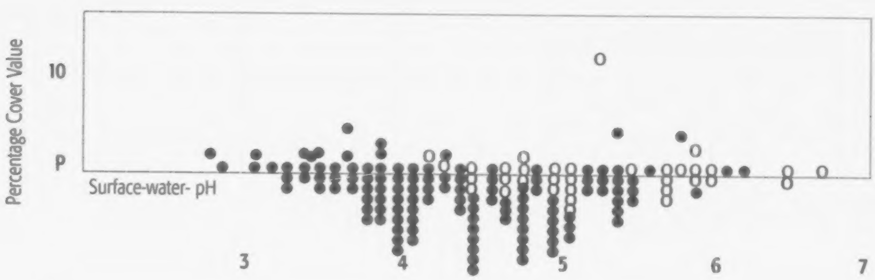
- o Ecoregion 0E/1E
- • Ecoregion 2E



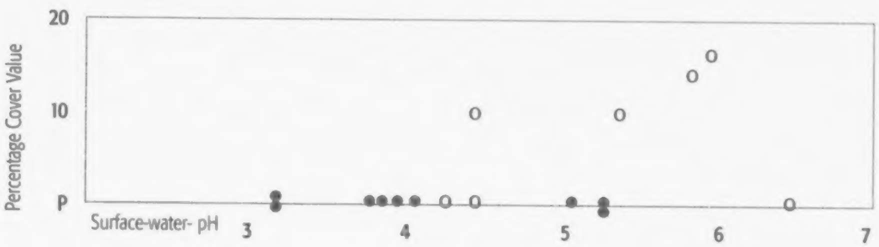
o Ecoregion 0E/1E
• Ecoregion 2E

Note: Multiple occurrences at Present (P).

Tomenthypnum nitens



Vaccinium oxycoccus



Vaccinium uliginosum

Appendix E
Species Name Synonyms

The Latin binomials for vascular plants follow ***The Flora of the Hudson Bay Lowland***, (Riley 2003). Synonyms are provided below, where subsequent synonyms have come into use since (***Flora North America***).

The Flora of the Hudson Bay Lowland	***Flora North America***
Sparganium chlorocarpum	*S. emersum*
Scirpus acutus	*Schoenoplectus acutus*
Scirpus cespitosus	*Trichophorum caespitosum*
Scirpus hudsonianus	*Trichophorum alpinum*
Scirpus maritimus	*Schoenoplectus maritimus, Bulboschoenus maritimus*
Scirpus rufus	*Blysmus rufus*
Tofieldia glutinosa	*Triantha glutinosa*
Smilacina trifolia	*Maianthemum trifolium*
Alnus crispa	*A. viridis* ssp. *crispa*
Alnus rugosa	*A. incana* ssp. *rugosa*
Salicornia europaea	*S. maritima*
Potentilla anserina	*Argentina anserina*
Potentilla fruticosa	*Dasiphora fruticosa* ssp. *floribunda*
Pontentilla palustris	*Comarum palustris*
Cornus stolonifera	*C. sericea*
Ledum decumbens	*L. palustre* ssp. *decumbens*
Andromeda glaucophylla	*A. palustre* var. *glaucophylla*
Rhinanthus crista-galli	*R. minor*
Aster robbynsianus	*Symphyotrichum robbynsianum*
Chrysanthemum arcticum	*Dendranthema articum*
Senecio aureus	*Packera aurea*
Senecio pauperculus	*Packera paupercula*

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The Hudson Bay Lowland supports the world's third largest wetlands, and the largest in North America. Eighty-three percent of it lies in Ontario, at the core of the world's largest intact boreal landscape. It is one of the world's densest accumulations of peat, measurably cooling the global climate by sequestering atmospheric carbon.

More than 85% of the Lowland in Ontario is either mineral wetland or organic peatland, much of it underlain by permafrost and the vast majority of it unforested. The Lowland emerged from the sea over the last 6000 years and is emerging still, and has evolved into an unparalleled array of bogs, fens, swamps and permafrost peatlands, and along its 1290-km ocean coast, an incomparable breadth and range of intertidal and supratidal marshes.

The wetlands of this remote wilderness ecozone provide globally significant habitat for breeding, feeding and migrating waterfowl and shorebirds, as well as still hosting all of its original fish and wildlife species. Its ecological significance and the imminent pressures it faces for mineral and energy development, underscore the critical need to enhance knowledge of the Lowland in support of sound land-use decisions, community wellbeing and superior environmental assessments. This study focuses on the Lowland's dominant wetland terrain and provides a regional overview, descriptions and keys to wetland types, analyses of ecological variation and succession, and a catalogue of wetlands surveyed.

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